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ON THE EFFECTS OF INSTITUTIONAL ARRANGEMENTS FOR INNOVATION IN CLUSTERS

- A COMPARATIVE CASE STUDY OF SUGAR CLUSTERS IN
SÃO PAULO, THE NORTH EAST OF BRAZIL AND CUBA



LUND UNIVERSITY

Jens Sörvik

On the Effects of Institutional Arrangements for Innovation in Clusters
- A comparative case study of sugar clusters in São Paulo, the North East of Brazil and Cuba

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List of Acronyms

ANAP	(Asociación Nacional Agropecuaria) National Association of Agricultural Production
APEX	(Agência de Promoção de Exportações e Investimentos) The Brazilian Export and Investment Promotion Agency
APLA	(Arranjo Produtivo Local do Alcool da Região do Piracicaba) The Alcohol APL of the Piracicaba Region
BNDES	(Banco Nacional de Desenvolvimento Econômico e Social) The Brazilian Development Bank
CCS	(Cooperativa de Créditos y Servicios) The Credit and Service Co-operative
CIESP	(Centro das Indústrias do Estado de São Paulo) The Industry's Centre of the State of São Paulo
Comecon	(Sovet ekonomicheskoy vsaymopomoshchi) The Council for Mutual Economic Assistance
Consecana-SP	(Conselho dos Produtores de Cana-de-Açúcar, Açúcar e Alcool do Estado de São Paulo) The Council for the Sugarcane Producers, Sugar and Alcohol in the State of São Paulo
Copersucar	(Cooperativa de Produtores de Cana-de-açúcar, Açúcar e Alcool do Estado de São Paulo) The Co-operative of Producers of Sugarcane, Sugar and Alcohol in the State of São Paulo
CPA	(Cooperativa de Producción Agropecuaria) The Agricultural Production Co-operative
CTC	(Centro de Tecnologia Canavieira) The Sugarcane Technology Centre previously the Centro de Tecnologia Copersucar,
ESALQ	(Escola Superior de Agricultura Luiz de Queiroz) Agriculture College Luiz de Queiroz
FAPESP	(Fundação de Amparo à Pesquisa do Estado de São Paulo) the State of São Paulo Research Foundation
IAA	(Instituto Açúcar e Alcool) the Institute for Sugar and Alcohol
IAC	(Instituto Agronomico de Campinas), the agricultural institute of Campinas
IB	(Instituto Biológico), the State of São Paulo's Biological Institute
ICIDCA	(Instituto Cubano de Investigaciones de los Derivados de la Caña de Azúcar) Cuban Institute for Sugarcane derivatives Research
ICINAZ	(Instituto Cubano de Investigaciones, Azucareras) Cuban Institute for Sugar-related Research
INCRA	(Instituto Nacional de Colonização e Reforma Agrária) The Brazilian Agency for Land Reform
INICA	(Instituto Nacional de Investigaciones de la Caña de Azúcar) Cuban Institute for Sugarcane-related Research

Inmetro	(Instituto Nacional de Metrologia, Normalização e Qualidade Industrial) The National Institute of Metrology, Standardisation and Industrial Quality,
IPEN	(Instituto de Pesquisas Energéticas e Nucleares), the Nuclear and Energy Research Institute
IPT	(Instituto de Pesquisas Tecnológicas), Institute for Technological Research (IPT).
MINAZ	(Ministerio de la Industria Azucarera) The Sugar Ministry
ORPLANA	(Organização dos Plantadores de Cana do Estado de São Paulo) The Organisation of Producers of Sugarcane of the State of São Paulo
PHB	(PolyHydroxiButirate), an organic composite synthesised by bacteria-eating sugar with properties similar to plastics
PIPE	(Programa Inovação Tecnológica em Pequenas Empresas) Technological Innovation in Small Business Programme
Planalsucar	(Programa Nacional de Melhoramento da Cana-de-Açúcar) National Programme for Sugarcane Enhancement
Pró-Álcool	(Programa Nacional do Álcool) National Alcohol Programme
RIDESA	(Rede Interuniversitaria para o Desenvolvimento do Setor Sucroalcooleiro) The Inter-University Network for the Development of the Sugar Alcohol Industry)
SEBRAE	(Serviço de Apoio às Micro e Pequenas Empresas) The Brazilian Support Service to Micro and Small Enterprises
SEMIC	(Secretaria Municipal de Indústria e Comércio) Municipal Department of Industry and Commerce of Piracicaba
SENAI	(O Serviço Nacional de Aprendizagem Industrial) The National Service for Industrial Learning
SESI	(O Serviço Social da Indústria) The Industry's Social Service
Sindaçúcar	(Sindicato da Indústria do Açúcar e do Álcool) The Union of Sugar and Alcohol Producers
SUM	(Sedes Universitarias Municipales) Municipal Universities
UBPC	(Unidad Básica de Producción Cooperativa) Basic Unit of Co-operative Production
UFAL	(Universidade Federal de Alagoas) The Federal University of Alagoas
UFPE	(Universidade Federal de Pernambuco) Federal University of Pernambuco
UNICA	(União da Indústria de Cana-de-açúcar) Union of the Sugarcane Industries

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1. Introduction

1.1 Setting the Scene

The focus for this thesis is how clusters can be conducive to innovation through so-called dynamic externalities (Bergman and Feser, 1999) and the ways in which institutional arrangements have an impact on the cluster externalities.

One of the most popular concepts in innovation policy research during the last decade has been clusters. There has been a notable rise in the number of scientific articles that explore the concept of clusters and related concepts (Maskell and Kebir, 2006). This is a theme that has attracted great interest for academic analysis and as a tool for policymakers and practitioners of regional development. The concept was introduced in the early 1990s by Michael Porter (1990, 1998) and his definition of a cluster is also the starting point of this thesis, *“a cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. The geographic scope of clusters ranges from a region, a state, or even a single city to span nearby or neighbouring countries (e.g., southern Germany and German-speaking Switzerland). The geographic scope of a cluster relates to the distance over which informational, transactional, incentive, and other efficiencies occur”* (Porter, 1998).

Porter's cluster concept builds upon a long tradition of economic theories addressing the role of externalities from co-location of economic actors active in a related economic field. What these theories have in common is that they describe clusters or local agglomerations as positive for firm efficiency, innovation and competitiveness, by creating externalities that reduce transaction costs and create opportunities for innovation (Malmberg and Power, 2006). The focus for this thesis is on the latter aspects.

The main mechanisms that create opportunities for innovation that have been identified in the literature and that will be explored in this thesis are: i) In clusters competition is tougher and more transparent, which drives firms to innovate more and in more productive ways (Porter, 1998; Power and Hallencreutz, 2002; Boarsi et al., 2003); ii) knowledge spill-over, i.e. there are secrets of the trade that diffuse in the air, by labour rotation and from

informal contacts, which makes it easier to start new firms and to develop existing operations (Marshall, 1890; Arrow, 1962; Romer, 1986; Storper and Venables, 2003); iii) Specialisation of labour and suppliers (Marshall, 1890; Lösch, 1954; Hoover, 1970; Piore and Sabel, 1984); iv) Cluster locations provide opportunities for user-producer learning which is an important input for firm innovation activities (Dahmén, 1950; Hirschman, 1958; Porter, 1990, 1998); and v) joint action clusters are locations where it is easier for small firms to collaborate in order to upgrade capabilities, goods and services and to undertake collaborative efforts (Piore and Sabel 1984; Maillat, 1991; Humphrey and Schmitz, 1995; Storper, 1999; Malmberg and Maskell, 1999) and appropriate locations for deliberative innovation policies (Helmsing, 2001; Borrás, 2003).

The cluster concept is not undisputed, however, and has received much criticism for being under-theorised (Asheim et al., 2006) and too vague (Martin and Sunley, 2003). Martin and Sunley (2003) have deconstructed the cluster concept and explored Porter's and other articles in which they found imprecision about how to practically delimit the cluster, geographically, about what critical mass is, the degree of relatedness of economic activities, and by claiming that clusters can vary in size depending upon their positions in a life cycle, e.g. emergent and stagnating cluster; there is a danger that anything can be defined as a cluster, making it hard to use as an analytical tool.

The cluster concept has become very popular in innovation research and among policymakers and regional development practitioners. However, the use of the cluster concept by practitioners is heterogenic, but still with similar expectations of outcomes. If one made a continuum of the most common ways of using the cluster concept among practitioners, one would find at one end locally anchored business networks of related economic activities or policy initiatives to support this, and at the other end pure agglomerations of related economic activities in a geographically confined area; a few examples are presented below. In Upper Austria there is a view of clusters as agglomerations and that cluster policies can boost the local economy: *"A cluster is a natural existing area of economic and technological strength. Consequent development of clusters is an essential part of the Upper*

*Austrian cluster policy, with the aim to boost the innovation efficiency of the companies when cooperating with other firms in their areas.”*¹ Sweden’s Biotech Valley is a policy initiative intended to generate a cluster, but it is not called a cluster. The organisation has five members, but offers a number of services in order to develop a local industry.² Some use the term cluster for a locally connected organisation; for example, the food cluster organisation in the Swedish County of Sörmland invites their members to a board meeting of the cluster at their website.³

In this thesis the challenges of definitions and usage of the concept are acknowledged, and at the same time the cluster concept is considered interesting enough to continue exploring, both from an analytical point of view and due to its popularity among academics and practitioners, but with the awareness of a need to better structure the concept.

For innovation to take place there is not only a need for an invention, but it has to be diffused and put into practice as well (Schumpeter, 1934; OECD, 2005; Fagerberg, 2004; Gault, 2010), implying that innovation takes place through interaction. Hence, to understand innovation, one needs to understand how transactions take place. Clusters are described as affecting innovation, by a number of externalities, i.e. effects that are outside direct interaction, but have an impact on others. Therefore it is important to analyse how interaction takes place in clusters in order to understand how clusters affect innovation. The particular interest here is to explore how the governance of transactions, in the form of different institutional arrangements in clusters, has an impact on innovation.

In order to do this an institutional analysis will be carried out. Institutional analysis explores how human interaction takes place, the relation between incentives, and which activities take place or are prevented (Hollingsworth, 2000). According to institutional theory, institutions are the fabric of social life that structure human activities and their exchange by explicit or implied rules (North, 1990; Hodgson, 2006). Institutions shape and reflect actors’

1 http://www.clusterland.at/740_ENG_HTML.php.

2 <http://www.BiotechValley.nu>.

3 Sörmlands Matkluster bjuder in till styrelsemöte – Swedish for Sörmland’s Food Cluster invites to a board meeting, (www.matkluster.se).

values and preferences and guide their behaviour. They affect who and what is included in decision-making processes, how information is gathered, processed and structured. Societies vary with regard to institutional set-up, with differences in the autonomy of actors and enabling systems for transaction, which affect the possibilities for societal change. There are a number of theoretical approaches arguing that actors at the national level are not co-ordinated or governed by a single type of institutional arrangement, and the degree of presence or the mix of arrangements varies between societies; the differences in institutional framework will have different impact on innovation and production outcomes, the most notable ones being Innovation Systems Theory (Freeman, 1987; Lundvall, 1992; Nelson 1993); Varieties of Capitalism (Hall and Soskice, 2001); Social Systems of Production and Innovation (Amable, 2000); and Social Production Systems (Hollingsworth, 2000).

The literature on governance of relations in clusters is not straightforward. For example, a reading of Porter can suggest a number of readings as to how relations in clusters are governed and how to define a cluster with relation to governance of relations. Porter (1998, 2008) suggests that clusters are conducive to competitiveness in different ways, partly through pure market-based transactions, but most advantages stem from relations. Cluster relations can be in the form of strong and weak ties guided by embedded social relations that facilitate collaboration: *“The benefits of trust and organizational permeability, fostered through repeated interactions and a sense of mutual dependence within a region or city, clearly grease the interactions within clusters that enhance productivity, spur innovation, and result in the creation of new businesses”* (Porter, 1998: 2008, p. 242). He also suggests that it is some sort of network: *“Clusters also represent an important forum in which new types of dialogue can and must take place among companies, government agencies, and institutions such as schools, universities, and public utilities”* (Porter, 2000, p. 16). He uses terminology suggesting it is some sort of association: *“A firm’s identification with and sense of community, derived from a membership in a cluster...”* (Porter, 1998: 2008, p. 242). He also talks about participation in clusters, which would also imply that he views clusters as related to locally based networks or associations, *“through facilitating complementarities between the activities of cluster participants”* (Porter, 2000, p. 22) and *“Cluster participation also offers advantages in perceiving new technological, operating, or delivery possibilities”* (Porter, 2000, p. 23).

When reviewing other authors, one likewise finds a broad view of institutional arrangements connected to clusters; often cluster itself is used as a term describing a particular form of governance that arise from repeated collaboration and local culture (Visser and De Langen, 2006). Similarly, there are some who define clusters as regionally anchored networks, in places with a critical mass of actors in related fields, implying one form of governance mechanism (Borrás and Tsagdis 2008). Others argue that cluster relations are socially embedded and that this influences activities in clusters, which differs from non-cluster relations that are controlled by arm's-length relations, giving a degree of path dependency and common intentionality to cluster activities (Nooteboom, 2000). The embedded relations make it easier to carry out activities, not only for private collaboration, but also for policymakers to involve private interests in deliberating policy (Helmsing, 2001). There is also a tendency for policymakers and related literature to think of policy initiatives as clusters (Malmberg and Power, 2006). In the policy literature clusters are frequently described as being based on small and medium-sized firms on an equal footing collaborating to meet global competition in new ways, due to an interest in clusters as tools to support SME competitiveness (Markusen, 1996). To address differences in the institutional set-up, typologies of clusters have been created, describing types of actors, dominant forms of relations and governance mechanisms and what type of outcomes of efficiency and innovation to expect (Markusen, 1996; Altenburg and Meyer-Stamer, 1999; McCormick, 1999; Parrilli and Sacchetti, 2006).

In the literature review no description was found of how the differences in institutional arrangements affect the way clusters have an impact on innovation. In order to address the objectives of the thesis an analytical framework has been created that establishes a vocabulary and serves as a basis to structure the data used for the analysis. The framework consists of three major building blocks: theories on innovation, cluster externalities and institutional arrangements. For institutional arrangements the point of departure is Hollingsworth (2000), who has created a framework for institutional analysis of innovation, in which he uses six categories of institutional arrangements that affect innovation. However, in relation to my empirical material and the findings of a large empirical study of dominant cluster relations which indicated that long-term relationships are by far the most common, followed by short-term coalitions, hierarchy, spot

market, and further down family and ethnically based transactions (Enright, 2000), Hollingsworth's categories have been altered.

Networks and associations have been merged, due to their similarity, and hierarchies have been removed as this is a study of inter-organisational transactions and communities were found to be irrelevant. Another important influence has been a framework to measure cluster performance in lowering transaction costs and creating collaborative regimes that analysed a number of institutional arrangements in the process, with the important piece of the role of leader firms (De Langen, 2004). Likewise Markussen's (1996) empirical description of cluster types, which emphasises the role of large and dominant firms in a number of cluster types, has been influential. Furthermore, there have been influences from analytical categories of institutional arrangements in global value chain theory (Gereffi, 1994), leading to the addition of the category of quasi hierarchies. The result is four analytical categories of institutional arrangements with differences in how interactions are enabled, by incentives and enforcement: i) markets, defined as being close to spot market activities, have strict regulation of behaviour and combine individual self-interest with horizontal co-ordination of transactions; ii) networks are looser voluntary arrangements of mutual interests based on repeated interaction; iii) quasi hierarchies are voluntary relations, but with asymmetrical power relations between actors; iv) the state – unique in that it has power to sanction and regulate the various other arrangements. The state is also nominally the one with the monopoly of violence and the ultimate enforcer of rules and various mechanisms. It defines property rights and manipulates fiscal and monetary policy. It has powerful tools to influence the incentive systems of the society. The state can also be an economic actor by engaging directly in the production of goods and services.

This thesis explores how the underlying institutional arrangements affect the ways in which cluster externalities have an impact on innovation, and the extent to which some arrangements relate more strongly to some externalities than others. Furthermore, it explores the interplay between arrangements, if there are dominant arrangements, and whether these enhance or undermine each other and the outcome for innovation. The reasoning is that in clusters there are a number of coexisting institutional arrangements that influence cluster externalities with an impact on innovation. The influence of cluster externalities on innovation differs

depending on the underlying arrangements, as these provide different incentives and means for enforcement that form the behaviour of the actors and the methods and sources of innovation that will be employed. The arrangements interplay and influence each other, and in some societies some modes are more dominant than others, influencing how the other modes operate and affect which styles of innovation will occur. For example, in some countries there has been legislation with the ambition to limit competition among existing actors, to strengthen the incumbent's position and reduce threats of bankruptcy; with this type of legislation the pressure for innovation was reduced, but it limited the entrance of new firms, meaning that the cluster externalities from intense competition would be reduced (Maloney, 2001; OECD, 2009).

1.2 Choice of Cases

This study has an exploratory point of departure, originating in a search for how clusters can support innovation in agricultural clusters in Latin America. The reason was previous experiences both of clusters and of Latin America. I have previously been involved in a project on cluster policy (Andersson et al., 2004) and worked and travelled in the region, which aroused my interest in further projects in the region. Much of the literature on clusters that I had come across previously was geared towards the developed world, which triggered my interest in learning more about clusters in developing countries and in particular in Latin America: how are they constituted, what kinds of activities take place and what kind of influence do they have on innovation and upgrading? The agro-industry was chosen due to its importance for the regional economies.

As the project was of an exploratory character, a comparative case study method was chosen, allowing for in-depth study of the subject and at the same time enabling me to generate findings of a more generalised character, through comparison. The work process has been such that the focus has been narrowed over time, with closer limitation regarding economic activities, from the agro-industry to the sugar industry, and geographically from Latin America to Brazil and Cuba. In the process it was found that the sugar industry is an industry with clusters, and where innovation and upgrading have taken place; e.g. in Brazil, approximately 80% of the sugarcane is harvested in the Centre South of the country, and the other

20% is produced in the North East. It is also a broad and complex industry with low- and high-tech features, connecting both rural and urban actors, consisting of a web of a number of economic activities, such as sugarcane production, sugar production, ethanol, alcohol, electricity production, and derivatives such as paper board, yeast, animal feed, and other by-products. Innovation has occurred in many different forms in all of these cases, and it is of interest to explore how this relates to clusters.

Furthermore, in Brazil and Cuba the sugar industries are important in driving economic growth, but to different degrees. In the 1990s Cuba was the world's major sugar exporter and Brazil the fifth; in 2004 it was the other way around (Pollitt, 2004). This alteration of importance of the countries as exporters was also an interesting change to explore; could this be somehow related to clusters and institutional arrangements?

When exploring the cases I found that one obvious factor that differed was the set-up of institutional arrangements. Cuba is a planned economy and Brazil a market economy. The institutional arrangements have also varied over time in the cases.

In Cuba the state is dominant in all institutional sectors, but there are also other arrangements in place, such as co-operatives, firms, joint ventures with foreign firms. In 1993 there was a radical institutional shift, when their collaboration with Russia and the Eastern European countries ended. Cuba entered what is called the Special Period, where there have been periods of decentralisation, with less centrally planned features of the economy, but then periods with recentralisation (Brundenius, 2002). The sugar economy has over time also been in and out of favour of with government, which has also had an effect on the efforts and resources diverted to the sector.

Brazil's being a large economy provides an opportunity to compare two institutional settings within a country, with differences and similarities. The two cases under scrutiny, the North East (Pernambuco and Alagoas) and São Paulo/Piracicaba have also quite different development trajectories with differences in innovation outcomes and economic growth. The latter is the most advanced part of the country and the former the least developed. The differences seem at times as large as those between developed and developing countries. Brazil has also had notable shifts in the institutional arrangements governing the sugar sector, and a key turning point for the Brazilian cases came in the 1990s, when the political economic framework was altered from

high degrees of government intervention in structuring market relations and regulation of prices and quotas, to more liberalised and market and network arrangements. The focus of this thesis is on the period 1970–2010, as there was a surge of domestic technological capabilities in both countries in the 1970s, with a shift in the institutional framework at the beginning of the 1990s and with different outcomes for the countries in the development over time. These similarities in time periods make the comparison more interesting and relevant.

After a review of the cluster literature and initial exploration of the empirical material, a gap in the literature was found that this thesis aims to address. By comparing the Brazilian and Cuban cases, the objective is to explore how the institutional arrangements in the clusters affect the externalities that have an impact on innovation and to explore the importance of this for the outcome of innovation in the clusters in the empirical cases.

1.3 Aim and Research Questions

This thesis has two main objectives and four research questions.

The first aim is to explore how institutional arrangements influence cluster externalities and their impact on innovation.

In order to succeed with the aim, there has been a need for further clarification of what institutional arrangements, clusters and innovation are and how these components interact. The main theories about these concepts are presented in order to establish a vocabulary for the analysis, but also to serve as sensitising concepts, which are used to identify elements that should be studied further, and in a similar way the analytical framework is used as a sensitising scheme that gives guidance to address and analyse the material rather than a theoretical proposition that is tested. Data have been gathered from quantitative and qualitative sources and are structured into the analytical categories, in order to identify how institutional arrangements relate to cluster externalities and innovation.

When analysing the empirical material, I have posed the following research questions:

1. **What institutional arrangements, cluster externalities and innovation outcomes can be identified in the cases?**

2. How do institutional arrangements influence externalities in the clusters?

The second objective is to find out how the cases differ in innovation performance, and whether this can be attributed to cluster externalities and the set-up of the institutional arrangements in the cases.

For this purpose I have posed the following research questions:

- 3. What is the institutional set-up of the sugar clusters in São Paulo, the North East of Brazil and Cuba, and how have they evolved over time?**
- 4. What has the innovation outcome been in these sugar clusters?**

1.4 Outline of the Thesis

Chapter one gives an introduction to the thesis. Chapter two presents the theoretical concepts that will be explored: innovation, cluster theory, and institutional arrangements. The purpose is to establish a vocabulary and to create an analytical framework, which is presented at the end. Chapter three is about the methodology of the thesis, with descriptions of the object of study, the research design with a discussion of how the work has been structured and how methodological challenges have been met.

In chapter four, the empirical material is presented and analysed. It begins by describing the development of the sugar industries and is followed by a description of the institutional set-up of the three clusters. This is followed by a section on the innovation outcomes of the cases. After this is a presentation of the four categories of institutional arrangements and their effect on cluster externalities, and the impact on innovation for each case. Each case also has a summary section that presents the main findings of the cases. In chapter five the cases are compared with an analysis and discussion of the main findings from the cases, with regard to how the cluster externalities are affected by the institutional arrangements and the impact on innovation in the cases. In the final chapter the findings of the thesis are summarised and discussed; this includes discussions of implications for policy, boundaries and generalisation and suggestions for future research.

2. Theory

2.1 Innovation

Innovation is a driving force for societal and organisational renewal. Innovation raises productivity through which individuals increase their standards of living. For firms it is a way to stay long-term competitive, by improving products and processes and by introducing innovations that are far superior to existing solutions that cannot respond to this through increased efficiency in existing production (Schumpeter, 1934; Gibbons et al., 1994). Innovation can also mean new products and processes to meet new challenges, for example more environment-friendly technologies.

In this study I have used OECD's (2005) definition of innovation; "*An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.*" What is a product innovation for one organisation is a process innovation for another organisation. These innovations can be new to an organisation, new to the market or new to the world. In this study, to restrict the number of categories of analysis, two main categories in which all other types of innovation can be grouped will be used, product innovation and process innovation. Linked to innovation is the concept of upgrading, which is common in development economics literature. Pietrobelli and Rabelotti (2004) define upgrading as: "*innovating to increase value added*"; it is a process to raise the quality of products, processes, capabilities of the firm, organisation and business models (Humphrey and Schmitz, 2000).

Another important distinction is that between radical and incremental innovations. Radical innovations create fundamental changes in an industry; they reduce the value of prior knowledge and create uncertainties within existing organisations. An incremental innovation is a minor change that strengthens prior knowledge within an organisation.

New technologies come from a combination of matching needs with methods to control natural principles that address the need (Arthur, 2010). Innovation processes resemble how new technology is developed, but innovation is different from inventions in that it is applied: "*Invention is the*

first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice” (Fagerberg, 2004). Where invention can take place in isolation, innovation is by definition taking place in interaction. Innovation comes as new products from established organisations, as start-ups around a new technology, or from improved processes and arrangements to deliver the product. Innovation is about new technology being integrated into social structures, such as firms and societies, which means change. This challenges incumbent actors relying on established practices, tearing down old structures and creating new ones, a process that the nestor of innovation studies, Joseph Schumpeter (1934), called creative destruction.

There has historically been a view of innovation as a linear process, where basic science generates new knowledge that is further refined, by applied science, engineering and then commercialised by an entrepreneur or a firm. However, the present conception is that innovation happens in a systemic fashion, where science is not the main driver of innovation, but just one component. Furthermore, there is constant feedback between innovating basic science, engineering and firms (Kline and Rosenberg, 1986). For innovation there is a need to interact with many different types of actors, to generate the technology, to organise suppliers and labour to deliver to customers. Innovation System literature which emphasises that innovations occur in interaction between firms, and between firms and knowledge exploring organisations like universities and research institutes, has grown vigorously (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edqvist, 1997).

There are many different types of sources of innovation, both internal and external (Drucker, 1985), such as: employees; internal R&D; business intelligence; imitation of competitors; new knowledge from universities and research institutes (new scientific and technological findings, and education of the labour force); the public sector (through changes in regulation, public procurement, public services (such as business support) and research programmes).

Innovation and the generation of knowledge are increasingly stressed in economic (Romer, 1986 and 1993; Lucas, 1988; Grossman and Helpman, 1991; Dunning, 2000) and business management literature (Porter, 1998; Ramirez and Wallin, 2000; Wallin, 2006); not only for traditional high-tech industries, but also for traditional sectors such as agriculture (Cramer, 1999;

Hirsch-Kreinsen et al., 2003; Mytelka and Farinelli, 2003; Morrison et al., 2008). There has also been a shift in emphasis on how to organise activities away from an ability to produce large series cost-efficiently (Drucker, 2001) towards more flexible specialisation (Piore and Sable, 1984).

Technology has become more complex and relates to a greater variety of knowledge bases. The knowledge needed for most activities has become highly specialised, and there is a need for full use of resources or it will deteriorate (Arrow, 1962), which is a problem of large all-encompassing firms. The time span between the creation and the dissemination of new products and their life cycle has decreased, which puts a higher pressure on firms to find the right products and make them profitable more quickly. At the same time, the costs involved in development have increased, making the risk of being left behind with the wrong technology more costly.

To adapt more quickly, large firms are disentangling vertically and horizontally, and even though many firms are still growing in size, these tend to focus more on core competencies (Prahalad and Hamel, 1990) and outsource less central activities, also seeking collaboration with external partners (Chesnais, 1988). Firms are going international in order to seek new markets or to find better suppliers, but also in order to acquire better knowledge and more competent labour (Reddy, 2000).

External and international relations seem increasingly important, and with falling prices for communication and transportation distance ought not to matter. At the same time there are observations of important agglomerations, such as Silicon Valley, and that their importance seem to be increasing. Porter (1998, 2000) has argued that external relations are the most important for firm competitiveness, and especially local ones. His argument is that external sources further away are available to everyone, and therefore from a competitive point of view are equal to everyone, but that the local relations are unequally distributed and therefore the ones that can create a competitive edge.

Innovation is a process of association and combination, where it is very important to have knowledge of partners and holders of different knowledge fragments that can be combined into new innovation (Arthur, 2010). Knowledge is also often tacit (Polanyi, 1962), which makes it hard to transfer, as not all labour is mobile. Furthermore, who and where to find knowledge is not equally easy to access, and in clusters it can be easier to

find relevant partners with whom it is easier to initiate collaboration processes (Nooteboom, 2006). To be located in a dense cluster, where it is easier to find potential partners with knowledge and to set up collaborative endeavours, is therefore a competitive advantage. Due to the dense local market and development of specialised suppliers, there are often complementary assets established, which are necessary for taking knowledge to the market, such as knowledgeable investors, manufacturing, distribution and marketing channels, after-sales and technical services, complementary technologies, marketing and professional services (Teece, 1986). The emphasis on local relations has been challenged, and others emphasise that it is global R&D recourses that matter (Doz et al., 2001). Others stress that local and external relations seem to be complementary (Bathelt et al., 2004; Coenen, 2006; Moodysson, 2008). More specifically, there is research suggesting that clusters matter differently depending on technology life cycles, and that clusters seem to matter more in early phases, as tacit knowledge matters more, but that in more mature phases knowledge and innovation are more dispersed (Audretsch and Feldman, 1996).

2.2 Cluster Theory

In this section the cluster externalities that influence innovation will be presented in more depth, after a historic introduction and a critical discussion of the concept.

2.2.1 History of Cluster Theory

The person normally identified as introducing the underlying thoughts that are at the basis of external economies of a location is Marshall (1890). He introduced the theories about industrial districts, as a means to explain why firms co-located in an economy. According to Marshall's theory, clustering began due to the location of either specific infrastructure, natural resources, favourable local conditions, special rights from an authority that allows certain activities in a special place or competencies. When the agglomeration is in place there are processes that stimulate further agglomeration and the creation of a benevolent circle (there are negative effects as well). The benevolent circle will create a network effect where it is beneficial for further firms and labour to relocate or remain in a cluster, due to the present externalities, and a disadvantage not to co-locate. The main external

economies of scale that Marshall brought up were knowledge spill-over, labour market pooling and specialised labour and suppliers; he also mentions the role of strong local demand.

Later, other scholars identified a relationship between geographic agglomeration and scale economies. Weber (1909) explained an individual producer's localisation decision as driven by the benefits of minimising production and delivery costs, assuming that this is only possible with one production site. Christaller (1933) depicted the demand and supply of goods and services as centralised but also characterised by spill-over that diminishes with distance. Central regions are surrounded by peripheral border areas with low market activity. Lösch (1954) coined the term agglomeration economies, which elaborates on a similar theme and focuses on the benefits of concentrating activities in one location. He distinguished between urbanisation economies referring to advantages of being co-located, and localisation economies, which are advantages of co-location for related firms. The external economies of scale in urbanisation economies stem from the geographical proximity of industries and services in general (Hoover, 1970). In contrast, localisation economies emanate from the geographical agglomeration of related activities, i.e. benefits resulting from the local access to a specialised workforce or the specialised reputation of a locality (to which some but maybe not all of these specialised activities contribute). Others call this MAR externalities and Jacob's externalities. MAR spill-over gets its name from Glaeser et al. (1992), who combined the thinking of Marshall (1890), Arrow (1962) and Romer (1986), and these externalities occur due to co-location of related industries, and Jacob's externalities due to co-location of actors (Jacobs, 1969).

In the 1980s the ideas about industrial districts were picked up by a number of scholars behind the theories of new industrial districts. These authors often focused empirically on the part of Italy called the third Italy (Becattini, 1987; Brusco and Righi, 1989; Dei Ottati, 1994). A number of strong clusters were located in the region. These held strong positions in world markets in a number of traditional product categories, including shoes, furniture, tiles, musical instruments, etc., without competing with low salaries. Success seemed to stem from an ability to rapidly produce relatively large volumes, but with niche and specialised products, of good quality and good design, so-called flexible specialisation (Piore and Sabel, 1984). This was seen as a possible response for firms and regions to the increasing

competition arising from globalisation. Regional co-operation and competition between firms is a way to flexibly and rapidly respond to markets demands, which is more challenging for large-scale mass manufacturing (Piore and Sabel 1984). Through individual specialisation in different niches of a similar industry, firms in a region can better respond to market demands; at the same time firms can collaborate in order to achieve economies of scale to meet large orders. Collaboration was seen as a way to reduce risk and increase efficiency, often called collective efficiencies (Humphrey and Schmitz, 1995; Schmitz, 1997). The term collective efficiency entails both the component of externalities and a component of joint action, which means that firms collaborate in order to strengthen their competitiveness. A recurrent theme of the industrial districts literature is social capital and trust-based relations. The local clusters are supposed to share a common culture and business practices that make local collaboration easier (Storper, 1999).

The GREMI⁴ School identified how local environments were conducive to collaboration and innovation, so-called innovative milieus (Maillat, 1995). The emphasis was that local relations and trust facilitate collaboration that can lead to innovations. As in research on industrial districts, they focus on alliances and partnerships between firms, but more on how the relations support a collective milieu for innovation and less on bilateral relations.

There is an increasing group of scholars who relate clusters to the dynamic externalities of localised learning and learning regions (Pinch and Henry, 1999; Keeble et al., 1999; Malmberg and Maskell, 1999, 2006). The argument is that the key source of long-term competitiveness for firms and countries is the generation of innovations through new knowledge. However, some of the strategically most important knowledge is not easily codified or transferred over distances, but is embedded in people, so-called tacit knowledge (Polyani, 1962), which does not float in the air but moves between firms through people (Giuliani and Bella, 2005). Tacit knowledge is also developed in organisations through its practices, routines and business climate (Nelson and Winter, 1982), and even in regions that develop specific forms of inter-organisational collaboration (Malmberg and Maskell,

⁴ Groupe de recherche européen sur les milieux innovateurs.

1999). These practices lower transaction costs and are also conducive to joint action.

The business strategist Michael Porter (1990, 1998, 2000, 2008) was the one who popularised the concept of cluster. Porter had come to the conclusion that standard classical theories on comparative advantage were inadequate or wrong, and that in order to understand how nations acquire competitive advantage one must understand how a nation's firms become competitive. For this purpose he connected micro perspectives of firm strategies, macro contexts of national economic policy and legislation, meso level perspectives of regions, in particular with specialised supplier networks and advanced local demand. Firms can increase their productivity and competitiveness by innovating, regardless of whether the industry is low-tech like the shoe industry or high-tech; all industries can employ high technology and increase their knowledge intensity. The national levels of productivity are set by the level of sophistication that a nation's firm compete on, which will decide levels of productivity and revenues. Porter had observed that technology and competition decreased the importance of location, but at the same time as there has been an increased globalisation there had been an increase in the concentration of co-located firms. Porter's answer to this paradox was that information and relationships that are accessible with communication technologies are available to anyone, so even though global sourcing reduces disadvantages, it does not create advantages. Localities that offer resources that are conducive to competitiveness and are hard to imitate and provide from other locations will have a strategic advantage.

Porter's view of a cluster has evolved over time (1990, 1998, 2000, 2008). There are some main parameters in his definition that alter over time, always present but not always the same; these are critical mass of actors, restricted geographical and industrial scope, and often they also include the need for commonalities and complementarities, and sometimes that the actors compete and collaborate. Porter's view is that clusters connect many traditional industries and depart from functional interlinkages horizontally and vertically. Vertical linkages are buying and selling chains between actors and horizontal linkages stem from complementary products and or actors drawing upon similar resources, e.g. inputs such as capital, technology or labour. Organisations are geographically proximate and concentrated, with a

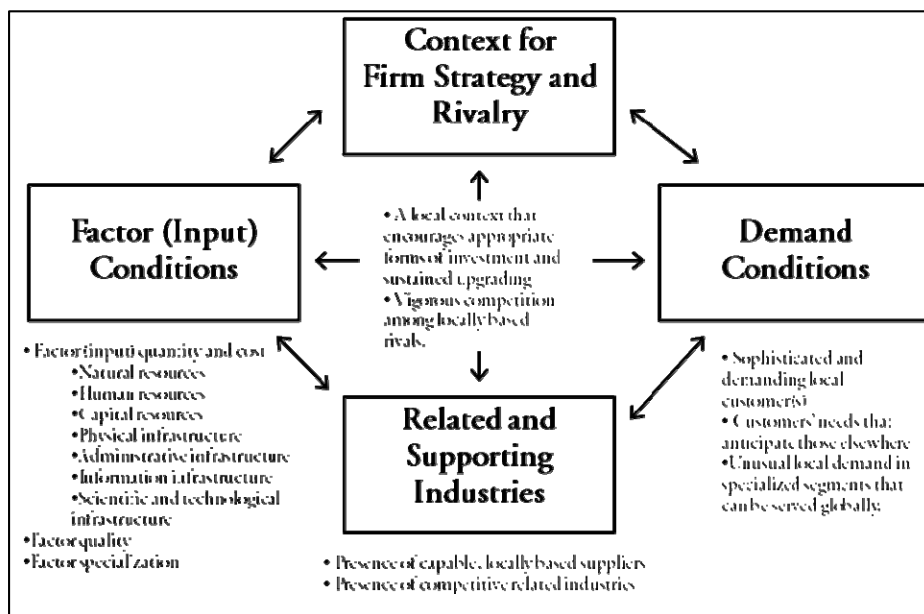
notion of critical mass, which strengthens the networks of direct and indirect links.

The first time that Porter used the term cluster was in 1990; at that time the geographical distance was less emphasised and the scope could be up to the size of a nation or more, as in his case of the mobile telephony cluster of the Nordic countries, and the actor focus was purely on firms. From 1998 onwards the geographical scope has been more emphasised and limited in size and he has also incorporated more types of actors in the definition of clusters, such as standards organisations, trade associations, vocational training agencies, universities and research institutes.

“A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. The geographic scope of clusters ranges from a region, a state, or even a single city to span nearby or neighboring countries (e.g., southern Germany and German-speaking Switzerland). The geographic scope of a cluster relates to the distance over which informational, transactional, incentive, and other efficiencies occur.” (Porter, 1998)

To Porter clusters provide the main input to a firm's competitiveness; it is therefore imperative for firms to locate in the right place, but also to participate in processes with other actors and government to develop the localities. The relation between a cluster and the inner dynamics that support the competitiveness of firms located in a cluster is described in Porter's diamond model, see Figure 1. The diamond consists of four categories: i) factor inputs, such as skilled labour, capital resources and infrastructure; ii) demand conditions, i.e. sophisticated customers in home market; iii) context for firm strategy and rivalry, i.e. conditions for organisation of companies, and the nature of domestic rivalry; and iv) related and supporting industries. Proximity from co-location of firms, suppliers and customers and other institutions provides a dynamic environment that stimulates productivity growth, new firm formation and innovation and upgrading.

Figure 1: Sources of locational competitive advantage



Source: Porter (2000)

The four points of the diamond constitute a self-reinforcing *system* that will promote clustering. The presence of strong and competing firms in a locality will increase the division of labour and specialisation, as there will be a demand for an increased supply of specialised intermediate goods and provision of specialised factor inputs. A large industry, as we saw in previous sections, will create a market where labour and firms dare to take the risk of specialisation, as the risk is lower and the reward is higher both for suppliers and labour. The local competition will stimulate more sophisticated consumers that will expect more innovative offerings. When a locality is becoming more competitive, outside firms will want to invest in the cluster, in order to reduce transportation costs, tariffs, communication costs, inventories, etc. This will further stimulate cluster growth and increase the dynamics.

Porter has identified three main categories of competitive advantages to firms from clusters: i) they increase the static productivity; ii) they increase the capacity of cluster participants for innovation and productivity growth;

and iii) they stimulate new business formation that supports innovation. Porter argues that clusters are conducive to innovation through:

- i) better access to specialised inputs and labour
- ii) better access to information
- iii) beneficial complementarities in place
- iv) better access to important institutions and public goods
- v) incentives and performance measurement
- vi) better perception of new buyer needs
- vii) perception of new technological, operating, or delivery opportunities
- viii) better conditions for new firm start-up

There have been a number of cluster studies exploring empirically in which ways clusters are beneficial. Brenner and Mühlig (2007) have made a large meta-study of 159 other case studies of clusters, and found that the factor that was most frequently referred to as important to the self-augmenting processes is: i) the accumulation of human capital and specialisation of skills. This was followed by: ii) co-operation among firms; iii) choosing to co-locate with other firms; iv) intra-industrial spill-over; v) interaction with public education and research; and vi) spin-offs.

There are other studies exploring whether it is more important to have related or diverting skills, whether MAR or Jacob's spill-over is more important. There seems to be more support for MAR spill-over, but there is some contrary evidence. Glaeser et al. (1992) support Jacob's skills, after finding that employment growth in cities between 1956 and 1987 is negatively correlated with industry growth, whereas if there is diversity, growth of employment is positive. Henderson (1997) explored employment data in US counties between 1977 and 1990 and found that firms grew quicker if there was concentration of skills. Henderson found some evidence for diversity, although on a much smaller level. In 2003, Henderson explored data on manufacturing establishments 1972–1992 and found that concentration of industry had strong effects on productivity. Data on knowledge flows between industries from research on patents support MAR externalities (Acs, FitzRoy, and Smith, 1999). An analysis of specialisation in Europe finds that it is correlated with growth in most industries, except for textiles and primary metals (Dalum, Laursen and Verspagen 1996).

The higher productivity and innovativeness of clusters should be reflected by higher salary levels than in non-clustered locations. Wheaton and Lewis (2002) explored worker data from 1990 across 220 metropolitan areas and found that specialisation in occupation and industry was positive for wage levels; a doubling in concentration of employment leads to a 2% wage increase. Gibbs and Bernat (1998), exploring similar data, found that wages for labour in industry clusters were 6% higher than in non-clustered locations. Drennan et al. (2002) found higher wages in manufacturing and producer services in locations that specialise, but lower wages in locations that specialise in distribution and consumer services. One should be rather cautious with this data, as the empirical data in the studies do not necessarily reflect an entire cluster, as they most often concern different industry categories that may not catch the entire cluster dynamics. Furthermore, diversity is often correlated with urban size; larger metropolitan areas have more diversity due to their size, and can also contain many specialised clusters. It can therefore be difficult to disentangle the effects of diversity and specialisation.

2.2.2 Critique of Cluster Theory

The cluster concept has received much critique, one of the most notable articles being by Martin and Sunley (2003). They present a number of arguments against the cluster concept and the way that Porter communicates in his articles on clusters. They argue the concept is saying that anything and everything is a cluster. They go so far as to say that the cluster concept may be a mere branding project with little substance, but that it has positive connotations and has become popular among policymakers and practitioners as it leaves it open for them to put their own meaning into it and use it for their own purposes.

First of all they find that the geographical scope is too loosely defined, from nation size level to city level. Porter's (2008) response is that cluster theory should be seen as a heuristic tool that guides the analyst, where distances, scope and the amount of actors are a matter of degree and need to be handled through a creative process, where the analyst needs to know the field, the industry, the niche, the strategy, the country setting, and to understand which spill-over matters for productivity and innovation. With an overly restrictive definition, relevant interlinkages may be obscured. Some types of cluster dynamics may be more or less dependent on the different

delimiting variables, and there are differences in dependence on geographical scope and related economic activity. However, a cluster is not the same as a particular industry or a sector such as manufacturing or services; that would mean failing to understand the important interlinkages that matter. Cluster boundaries also evolve over time, with changes in markets, technologies and institutions. However, he does not give any indication of what weak or strong ties are, or which clustering processes work at which scale. Still, he does not set any limitations, making it independent of scale and in its full extent meaningless. To further reduce delimitations, he talks about nascent, new, established, declining and potential clusters, which makes it possible to take almost any location and call it a cluster, but that they are in a different development stage. As Martin and Sunley (2003) put it, *"In practice, there are probably very few firms that do not have horizontal or vertical links (co-operative or competitive) of some sort with other loosely-defined 'geographically proximate' firms. Does this mean that virtually every firm could be considered part of a 'potential' cluster?"*

This fear is also to some extent confirmed in Porter's empirical arguments on the presence of clusters in the US economy, where he has claimed that clusters involved in external trade account for about 32% of total US employment (Porter, 2002). Unfortunately, he continues by saying that local clusters that do not trade externally, what he call local clusters, make up 67% of the US economy, giving a grand total of 99% of employees in the US are employed in a firm in a cluster. However, Porter elsewhere (1998) identifies approximately 60 significant clusters in the US.

Martin and Sunley continue by arguing that there is scant evidence for the connection between clusters and innovation, that it is mostly anecdotal and empirical studies are ambivalent (Beaudry et al., 2000; Best, 2001), whereas others do not prove any connection (Harrison and Glasmeier, 1997; Steiner, 1998; Segal Quince Wicksteed, 2001; Rodriguez-Pose, 2001). They continue to argue that clustering is not a panacea that will generate competitive advantage, but that the advantages are *"specific to certain industries at certain stages of development in certain places, and are only realized under particular conditions"* (Glasmeier, 2000). They point out that clustering is most significant in industries that are dependent on tacit or informal knowledge, often in pre-commercialisation stages (Audretsch and Feldman, 1996; Audretsch, 1998; Keeble and Wilkinson, 2000). Furthermore, there are surprisingly few empirical studies that have actually

provided convincing empirical evidence of the superiority of local over non-local interaction (Bathelt et al., 2004).

To meet some of this critique, there are scholars who have set out to create typologies of more narrowly defined clusters and attach different externalities to these, such as Malmberg with industry clusters that focus on the economic relational aspects of clusters, downplaying the geographical factor, and spatial or localised clusters, which emphasise the effect of local relations but with a loosening of the economic relatedness (Malmberg, 1999). Another approach suggested has been to use a multilayer approach (Gordon and McCann, 2000). The proposition is to carry out three separate but complementary analyses, either focusing on a pure agglomeration economics analysis, concentrating on localisation externalities, secondly, an industrial complex model analysis, with a focus on input-output relations that minimise transaction costs, and thirdly, a social-network analysis, exploring institutionalised practices.

Besides the criticism mentioned above, I also find it troublesome when reading his text that the direction of causality in his models and argument is unclear. It seems to me that he argues that some places have become clusters due to strengths in any parts of the diamond, which initiates the growth into a cluster, and the dynamics follows. Porter seems to argue that all agglomerations are clusters, and since they are agglomerations they are globally competitive. If they were not globally competitive there would not be an agglomeration, because it would be elsewhere. It is also somewhat unclear whether all clusters or all agglomerations also have all the beneficial process going on in clusters, or if some only have parts of them. If there are only parts of them, why do these processes occur? However, I believe that there can be agglomerations that are not clusters (they do not have a critical mass of actors in a particular industry), and clusters that are not dynamic or competitive. I share the view of Markusen (1996) that there can be other kinds of institutional arrangements that stimulate the growth of clusters; for example it is not certain that actors can observe local competitors in order to find the globally competitive front. The argument in this thesis is rather that there are different institutional arrangements in different clusters and therefore there are different dynamic externalities in place.

As described in the introduction, I also find that Porter is vague on the relation between the cluster concept and the institutional setting. He

definitely considers that the institutional setting matters, but he is vague as to whether a cluster should be seen as having many types of arrangements or being a type of institutional arrangement.

Despite these relatively harsh criticisms, I would like to follow the line of Nooteboom that cluster theory has a value, but that it is a work in progress. Nooteboom (2000) has said: *“the barring of concepts for being diffuse is inherently conservative, because new theory inevitably starts out with diffuse meanings. It is only later in the development of new theory, and novelty in general, that meanings become clear and practice settles down in a dominant design which is amenable to formalization”*.

If this is not enough, I would also like to say that, since the concept has been so massively and broadly picked up by policymakers, practitioners and academics, there is a need to further research and structure it and to engage in practitioner meetings to further clarify it.

2.2.3 Cluster Externalities Related to Innovation

Clusters influence innovation through externalities, which is a term that relates to benefits or drawbacks that are external to direct interaction, but that create benefits or costs for other actors (Bergman and Feser, 1999). These externalities are effects that are outside of direct individual transactions of organisations in the cluster, and are a result of the cluster characteristics of related economic activity, geographical delimitation and critical mass of actors. Clusters have been described as creating externalities that have an impact on innovation, by affecting internal and external sources, incentives and methods for innovation. In order to make the project operable, I have reduced the number of externalities to five categories: intense competition, knowledge spill-over, specialisation, user-producer learning and joint action. The way these externalities have an impact on innovation is summarised in Table 1. Each externality is described in the following sections.

Table 1: Influence of cluster externalities on innovation

Externality	Influence on innovation
Intense competition	More intense competition due to transparency and personal rivalry. Competition forces firms to innovate and seek out new niches. Danger of congestion and lock-in
Knowledge spill-over	Knowledge transfer from formal collaboration and informal contacts New knowledge input from labour rotation Easier to start new firms – complementarities and customers.
Specialisation	Easier to hire specialised labour, with more innovative input Greater market for specialised suppliers, with more innovative input Danger of Lock-in – cognitive and infrastructure
User-producer learning	Knowledge of market demand from leading organisations. Suppliers provide complementarities conducive to innovation
Joint action	Easier to collaborate, established business practices and shared cognitive frameworks Less need for regulation, due to trust and social monitoring Adequate partners for deliberating innovation policy. Danger of vested interests and cognitive lock-in

2.2.3.1 Intense Competition

Competition is a driver of innovation, as firms need to reinvent products and processes in order to stay competitive. In clusters there is more intense competition, due to a higher level of *transparency* originating from equal preconditions for the competing firms (Porter, 2000) and also a greater concentration of actors in a related field. Firms in clusters to seek out *specialised niches* and increase the economies of scope. Furthermore, Porter argues that the competition is more intense in clusters, as it is based on a *rivalry for local social standing*.

From competition there are pressures to improve. Depending on the institutional framework, actors may strive to gain advantage by reducing costs or prices, raising quality, acquiring new customers, or entering new markets. Porter argues that economies with low productivity are characterised by little local rivalry and that the majority of the competition comes from foreign offerings; in these cases competition is solely from prices and the strategy is to reduce wages. Porter argues that for an economy to

become advanced it needs to develop local rivalry and firms should compete by lowering total costs rather than lowering wages; this is done by upgrading the efficiency of manufacturing and service delivery. This relates to the concept of high and low roads of development to competitiveness (Sengenberger and Pyke, 1991; Humphrey and Schmitz 1995). The low road is related to extensive usage of resources, with low productivity and low wages, and the high road is more knowledge-related, innovative and specialised, with higher productivity and salaries.

Limitations to competition are often costly to society, especially in the long run. Barriers that rule out entry or advancement by newcomers may, for instance, bestow unhealthy privileges on incumbents, firms which can generate oligopolistic profits and block the development of innovations, and especially block the creation of new firms (Mokyr, 2002a). Only a limited number of technologies can be backed up within a given organisation, whereas more potential opportunities will be tested when new units are created through spin-offs (Kay, 2009). Porter argues that local competition is not only a cold and calculated competition, but a passionate one for social standing in the local group, and it is more transparent. *“Rivalry with locally based competitors has particularly strong incentive effects because of the ease of constant comparison and because local rivals have similar general circumstances (e.g., labor costs, local market access, utility costs), so that competition must take place on other dimensions. Second, the competitive pressure in a cluster is amplified by peer pressure, even among indirect or noncompeting firms. Pride and the desire to look good in the local community motivate firms to attempt to outdo each other”* (Porter, 2000). At the same time the local social relations are a way of keeping competition within socially acceptable boundaries, as shoddy activities will be punished by social monitoring.

Others argue in a similar fashion that competition is not faceless, but that competitors have knowledge about their main competitors in the market, as firms are specialised and there is division of labour (Boarsi et al., 2003). Normally firms recognise only a small number of competitors, due to limited cognitive abilities of humans (Porac and Thomas, 1990; Reger and Huff, 1993) and due to proximity in possibilities of observation competition is a localised phenomenon. In their study they point out that localised firms will compete more intensely (Baum and Mezias, 1992) and are more apt to perceive each other as rivals (Lant and Baum, 1995). Boarsi et al. (2003) found that firms in clusters compete with a limited number of firms, but

that they keep track of more competitors than non-clustered firms. They argue that there is more information available about local rivals, they share resources, have inter-organisational linkages and interact, which provides better opportunities to monitor a larger number of firms, and their products and processes.

Due to the local critical mass of actors competing in the same area, if they provide the same product they will have lower profits, as a result of which they will seek out different niches in order to distinguish themselves and these economies of scope, i.e. different firms offering varieties of products and services within a related segment create innovations (Dornberger and Budi, 2006). When firms seek out strategic niches they can also complement each other's offers. The local competition creates incentives to emulate best practice and it boosts pressures to innovate, but it also connects the strengths of competition with the virtues of selective co-operation, and these co-operative relationships with strong competitive suppliers strengthen the firm, offering even more than other competitors.

Successful clusters can grow to the extent that there is an overcrowding pressure from heavy usage of infrastructure and factor markets, with increasing transaction costs. In some locations this can destroy the originally beneficial preconditions for the occurrence in the first place and create a negative spiral (Pouder and St. John, 1996). Rises in property prices, living costs and salary levels can force suppliers to leave an area and prevent newcomers from establishing, which destroys the local dynamics (Arthur, 1990b; Grove, 1987; Portes and Landholt, 1996). In the short run there can also be limited access to key resources such as skilled labour and capital. At the same time the rising prices will be a force to divert more resources to firms in the region and a driving force for innovation (Utterback, 1974). It can also create environmental pressures due to increased use of land and resources.

There are also dangers that there will be under-investment in more long-term research and development and education, as much effort is geared at solving immediate concerns, with the result that there will be fewer resources available that are needed to be able to innovate in the long run (Arrow, 1962). In mature clusters, undifferentiated and more price-oriented competition can increase and benefits from cluster diversity will be

diminished (Canina et al., 2005), specialisation will fall and investment in science, technology and innovation as well.

2.2.3.2 Knowledge Spill-over

The main focus in the discussion of spill-over is on the role of knowledge and how knowledge is exchanged between individuals. Knowledge spill-over originates mainly from four factors: diffusion of knowledge through *informal* and *formal* contacts, *new firm creation* and *labour rotation*.

One of the most famous quotations from Marshall (1890) is about how knowledge is diffused in a cluster *“so great are the advantages which people following the same skilled trade get from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas. And presently subsidiary trades grow up in the neighbourhood, supplying it with implements and materials, organizing its traffic, and in many ways conducing to the economy of its material.”*

There is much empirical evidence of local knowledge spill-over being concentrated in clusters and being conducive to innovation (Jaffe et al., 1993; Baptista and Swann, 1998; Audretsch and Feldman, 1996) and also in developing countries (Kesidou et al., 2007).

There is an increased endeavour in the literature to show how spill-over takes place and that it is not a process of knowledge floating in the air. Knowledge is most often held by individuals tacitly (Polanyi, 1962) and is exchanged between people. Knowledge is diffused through informal relations (Schmitz, 1997), which has been referred to as lunch room effects (Camagni, 1991) or local buzz (Storper and Venables, 2003). People that are acquainted exchange knowledge informally and also unintentionally; in clusters relations are more densely located and therefore this type of interaction is more frequent (Storper and Venables, 2003). In clusters actors interact more frequently through weak ties, i.e. linkages between actors that are not strong or regularly pursued, but that can give knowledge impetus that is radically different, and hence bring the innovative ideas (Granovetter,

1973). Firms located in clusters have an advantage in understanding the local buzz in a meaningful and useful way, as the spatial proximity stimulates firms to develop similar language, technology attitudes, and interpretative schemes (Malmberg and Maskell, 2006).

There is also knowledge diffused in formal relations between firms (Fransman, 1985; Lundvall, 1988), such as supplier relationships (Morgan, 1997) and between firms and other organisations such as universities, through contract research, and people working part-time in different types of organisations (Jaffe et al., 1993). The direct contact with competitors, suppliers and customers is a good source of innovation, which is easier to pursue in a cluster, and therefore knowledge is stickier in these places (Von Hippel, 1988). However, not all firms are able to acquire knowledge spill-over, but there is a need for absorptive capacity (Cohen and Levinthal, 1990), i.e. the ability to rightly value, assimilate and apply knowledge and to belong to the right networks and have the skills to interact and transfer knowledge (Guiliani and Bella, 2005).

Another important way for knowledge to spill over is through labour rotation (Angel, 1989; Capello and Faggian, 2005) and new firm start-ups. Porter (2000) argues that it is easier to start new firms in clusters, as there is an “industry” framework with specialised suppliers in place. There is less need for initial investments to start up projects, as more parts of a project can be outsourced to localised specialised suppliers. It is also easier to grow due to access to specialised labour and it can be easier to find initial customers. It has also been found that new firm start-up and entrepreneurship is most often a local process. Firms are started in locations where the entrepreneurs have their networks, and where they have knowledge of available resources and capabilities (Feldman and Francis, 2004). Entrepreneurs use their prior experience when starting firms, which often happens in niches that are perceived to be non-fulfilled by established actors. Firms are often started as part-time projects or when people are laid off; these factors together with other reasons such as family mobility constraints, location preferences, and familiarity with the local context often make start-up connected to the original cluster.

2.2.3.3 Specialisation

The concentration of economic activity creates a large enough local demand to facilitate *specialised suppliers* and increased *local division of labour*, as

suppliers can increase specialisation and invest in more specialised machinery. There are also greater opportunities for *labour to increase their specialisation*, as there is a larger local market in the cluster. There is a potential danger that specialisation can create *path dependency* and *lock-in* to a technological trajectory that can be hard to break out of when there is a shift in technology.

In clusters there is not only a pressure to specialise to stay competitive, but there are also greater possibilities of rewards, as it is easier for suppliers and labour to find a market for specialised skills. The division of labour is a division of knowledge (North, 2006), where labour and suppliers can increase specialisation in knowledge and skills, both among exporting firms and among specialised suppliers such as lawyers, finance and advertising agencies. There can also be specialisation of research institutions, universities and think tanks, vocational training, standards agencies and trade associations that can provide specialised training, education, information, R&D, and technical support. Specialisation increases productivity and creates room for innovations, both from more specialised inputs in firms, but also from the creation of new products and services and modes of organisation. These specialised suppliers and intermediaries are very important holders of specialised knowledge, but also very important for diffusion of knowledge between organisations in the cluster (Giuliani and Bella, 2005). The specialised network of firms gives the cluster a competitive advantage, as it takes time and resources to build up specialised skills that are hard to imitate (Porter, 1998). By interacting with the most competitive suppliers, a firm's offering will be the most competitive as it is partly based on other competitive firms' offerings. In clusters there are also lower transaction costs and it is easier to initiate collaboration, as interaction is repeated. This interaction builds trust that reduces the need for formal contracts, and also reduces the costs of severing and recombining market relationships (Porter, 1998).

However, not only firms can specialise, but also labour in a district. As there are more opportunities for labour, but also more demand for more specialised skills, there is an opportunity for labour to take the risk and develop specialised skills (Marshall, 1890). Through the presence of more specialised skills, firms will be more likely to increase efficiency and also possibilities to innovate. It is also the accumulation of human capital that Brenner and Mühlig (2007) found was the most commonly reported factor

important for the self-augmenting processes of clusters in a meta-study of 159 cluster cases. The five following factors were most commonly reported: co-operation among firms; choosing to co-locate with other firms; intra-industrial spill-over; interaction with public education and research; and spin-offs.

If cluster theory is correct, wages would be higher in clusters, as they would offer opportunities for specialisation, and hence higher productivity and higher salaries. The higher productivity would result from better matching of workers to specific jobs, as there is better availability of skilled workers, and the labour force can be more specialised, and the knowledge spill-over would raise labour productivity, compared to non-clustered firms. In a competitive market, productivity will be reflected in higher wages. Cortright (2006) presents figures showing that a doubling in employment concentration in a particular industry results in a 2% increase in wages. The same author also quotes Gibbs and Bernat (1998), who found positive cluster wage premiums for 14 of 18 manufacturing industries in the US. Furthermore, they quote Nadvi and Barrientos (2004), who have found that wages for workers in clusters were about 6% higher than for non-clustered locations.

High degrees of specialisation can create lock-in, both infrastructure-wise and cognitively, that can be challenging to break out of in times of technological shift and can create social problems resulting from high unemployment, when there is no longer a demand for a certain skill. The actors in a region cannot in the short run change their activities completely, as their skills, machinery, operating procedures and the cognitive frameworks of the industrial landscape are strongly correlated with the present techno-economic paradigm and the development from previous positions (Nelson and Winter, 1982; Dosi et al., 1988). If local actors become too over-reliant on what appear to be successful strategies, they can fail to adapt to changes in technological trajectories.

2.2.3.4 User-Producer Learning

Clusters are locations with knowledgeable local actors and with possibilities for *user-producer learning* and *complementarities* that facilitate innovation through specialised demand signals.

In many clusters a local specialised demand exists that often originates from globally competitive firms, sophisticated local buyers and government regulations that force firms to alter behaviour, such as environmental legislation (Porter, 2000). Close proximity to consumers, with higher requirements and with demands that are ahead compared to other regions, will create better opportunities for firms to learn about and create innovations that will succeed elsewhere. It provides opportunities to learn about new prospects, both through observation of suppliers, partners and local competitors and through knowing the global competitive frontier before others, and seeing new business opportunities before others do. By interacting with market leaders, firms can learn what world-class requirements are for delivering products and services, which is an important input in innovation processes.

In many clusters there are complementarities that are beneficial, such as complementary products for a buyer (e.g. joint packages in tourism or product and services packages), marketing complementarities, and improved alignment of cluster participants' activities, e.g. upgrading to new standards for all of a vertical value chain and also a greater presence of complementarities in place (Porter, 2000). Complementarities create economic stimulus to suppliers and customers in the form of backward and forward linkages (Hirschman, 1958). Through its operations a firm and an industry can create backward linkages by demanding goods from suppliers for specific inputs necessary for their growing industry. The forward linkages come from a firm that provides goods to another firm. These demands and supplies will create linkages between firms that will spur economic growth. Complementary actors and technologies can be seen as development blocs, i.e. *"sequences of complementarities which by way of a series of structural tensions, i.e. disequilibria, may result in a balanced situation"* (Dahmén, 1950, 1988, 1991). A development bloc can be seen as a complex of factors that represent market demand and supplier competencies affecting technological trajectories, e.g. railways that lead to more efficient transportation and more efficient trade and lead to social restructuring with new complementary technologies and social organisation in the form of new cities. If there is a bottleneck situation and there is a rising demand for a complementary product or service it will be profitable to restructure parts of the economy. When complementary investments have been made, the development potential is fulfilled and there is a cumulative effect, a network externality

such that, when an increasing number of users of new technology appear, the total value of the technology rises. The initial gains from structural tensions flatten out after a while and some of the early firms will be outcompeted, and there is a concentration of firms in the industry that will further the efficiency of the production. The sources for disequilibrium most often come from new knowledge or new market opportunities. The driver of economic restructuring arises from synergies and complementarities of different technologies, investments, businesses and industries in generating innovations.

2.2.3.5 Joint Action

A recurrent theme in the cluster literature is that clusters arise in locations where it is easier to collaborate. In clusters there are *established business practices and shared cognitive frameworks* that have developed over time, reducing the efforts needed for collaboration. There is also less need for regulation and contracts as there is *social capital* and *trust* that both facilitates work processes and provides means for social monitoring. There is also an interest in clusters as locations for *deliberative action*, in identifying common challenges for actors to find solutions that can be jointly implemented. This can take place through different kinds of networks or state arrangements. In innovation policies it is often suggested that policymakers and businesses should engage in partnerships to formulate and implement policies. In clusters there is both a return on investment, making it worthwhile to engage in activities, and also potential partners to engage with in deliberating the policies. There are also challenges that collective action can be ways of protecting *vested interests* and locking out newcomers. Another challenge is from mental *lock-in*, due to the establishment of shared cognitive frameworks.

Local clusters share a common culture and established business practices that make local collaboration easier (Storper, 1995, 1999). Local institutions, conventions and customs for how to co-operate are established over time through repeated interaction (Nelson and Winter, 1982; Malmberg and Maskell, 2006), and business relationships grow into a weave of relations and interdependencies (Storper, 1995). There is a growth of habits and regularities that after a while are taken for granted, which reduces risks in transactions. There are what are sometimes referred to as traded interdependencies, i.e. a web of user-producer relations that facilitate

exchange. There is not only co-operation between individual firms, but also the establishment of different kinds of common institutions that can facilitate collaboration, such as testing and certification centres (Storper, 1999). Then there are untraded interdependencies, referring to phenomena such as labour markets, regional conventions, norms and values, which affect processes of economic co-ordination and organisational learning (Morgan, 1997).

In the literature on social capital it is also argued that in clusters it is not only business practices, but also the connection to the regional culture that facilitates interaction. Social capital is a production factor that enables collaboration process and the usage of human and physical capital. It affects the transaction costs, in the shape of shared practices and routines for co-operation due to a cognitive proximity (Boschma, 2005), and also in relation to monitoring costs, as people are likely to abstain from deviant behaviour if they expect to collaborate again in the future; moreover, relations are connected to social life and long-term social networks outside of the specific business deal. While human capital refers to the individual, social capital relates to the social fabric among individuals (Coleman, 1988). In order to exchange tacit and explicit knowledge and create new knowledge, there is a need to align individual cognitive perceptions and derive a group-level understanding as a basis for collaboration and diffusion (Nonaka and Takeuchi, 1995). Learning to understand counterparts and establish practices for collaboration is costly; however, the social capital in clusters, with established routines and practices, reduces transaction costs and facilitates collaboration, due to shorter cognitive distances (Visser and Boschma, 2004). Social capital is based on the notion that social networks are valuable and the members do things for each other through norms of reciprocity (Putnam, 1993, 2000). Social networks are of two types: bonding networks that connect people who are similar and uphold particularised (in-group) reciprocity, such as families, clans, regional cultures, religious groups, etc., and bridging networks that connect people who are different and nurture a generalised reciprocity, they often arise due to repeated interaction, where the norms of reciprocity and ways to interact

are established.⁵ In clusters there seems to be network and community effects that provide transaction cost advantages over other forms and seem to ameliorate many incentive problems. As a result of actors living and working in a close geographic area, their repeated interaction and often informal contracts foster trust and open communication, and reduce the costs of severing and recombining market relationships (Morgan, 1997). Geographic proximity between firms and research institutions tends to facilitate informal exchange and accumulation of tacit knowledge, and face-to-face contact remains very important for this (Saxenian, 1994). Granovetter (1985) has suggested that the relations between actors are not purely market-based, but socially embedded. Many have picked up on this thread and suggested that it is more so in clusters, where there is closer and more frequent interaction by actors.

Clusters are presently seen by many as optimal areas for addressing many joint public goods problems and as places with networks for implementing and deliberating industry and innovation policy. Clusters concentrate actors and interests, making it more efficient to carry out activities there; also these groups can concentrate their desires and influence policy more efficiently. In clusters actors come together to carry out joint activities, what is referred to as cluster initiatives in this thesis. Sölvell et al. (2003) have defined a cluster initiative “*as conscious actions taken by various actors to create or strengthen the competitiveness of clusters*”. It can create new possibilities for innovation, e.g. by setting up a joint research centre, or address negative cluster externalities, such as creating new infrastructure to break lock-in. These can be formal or informal, networks or organisations, long-term or short-term activities, purely private networks or public private partnerships including firms, government representatives and/or academia. It is quite common that these initiatives have been initiated by policymakers (Sölvell et al., 2003). The connection between policy and clusters is actually so strong that many when

⁵ Social capital does not have to be locally tied, but can pass over large geographical distances, as in the case of ethnic social capital. For example, India benefits from financial, commercial and knowledge flows of diaspora groups (Khadria, 1999), and Taiwan and Israel benefitted greatly in their industrial development from ethnic diaspora residing in the US, which facilitated financial and knowledge transfers. This can reduce opportunistic behaviour and decrease costs related to monitoring, which can lower transaction costs (Williamson, 1985, 2000).

referring to cluster initiatives many call them clusters, and especially such initiatives as have been publicly initiated.

Public goods can be delivered by state arrangements or networks, with the risk that some actors will be free riding on the arrangements or that vested interests will prevent changes or innovations. It is common that the state provides public goods. However, they need not necessarily be delivered by the state alone, but can involve other solutions. In the last two decades there has been an increase in solutions involving a mix of actors, known as Public Private Partnerships (Helmsing, 2001). Typically issues that are addressed relate to common infrastructure, mechanisms for resolving conflicts, education and science and technology. From a policy perspective the rationale is often to address market failures, i.e. desirable possible outcomes would not occur elsewhere. Typical market failures are that uncertainty among firms leads to under-investment in R&D, education (Arrow, 1962) or the development of innovative products, path dependency and lock-ins (Arthur, 1989, 1990a), where firms have invested and are built into systems running towards the end of a technological life cycle from which they have poor capabilities to move out. For this purpose governments have invested in programmes for R&D, retraining of labour and building of infrastructure.

Clusters as a policy tool have attracted interest as there has been a desire to find new ways to stimulate industry, due to disappointment with traditional industrial policy tools that often failed to create competitive industries and instead fostered rent-seeking and corrupt firms (Nauwelaers and Wintjes, 2002; Mattsson, 2007; Europe Innova / PRO INNO Europe, 2007). Other parts of traditional industrial policies such as tariffs and trade barriers have tended to lead to a situation where there is little pressure to innovate and often also to a situation where firms gain more from importing and implementing a technology than developing a new one (Maloney, 2001). Countries have also signed international trade agreements, prohibiting them to carry out policies of direct subsidies and they are therefore looking for new means of support. The interest in Science, Technology and Innovation (STI) policies as tools to stimulate their industry has risen. Furthermore, new theories related to innovation, so-called innovation systems and cluster theory grew out of a co-development of academics (Rosenberg, 1982; Nelson and Winter, 1982; Freeman, 1987; Lundvall, 1992) and policy organisations (OECD, 1999, 2001a, 2001b; UNCTAD, 1994, 1998; the

European Commission, 2001) (Mytelka and Smith, 2002). These theories emphasised interlinkages between firms, policymakers and academia.

The emerging policy recommendations are geared to stimulating innovation systems and clusters, through a combination of top-down and bottom-up initiatives linking firms, policymakers (from different agencies, education, industry, S&T) and academia in more horizontally oriented, regionally focused, decision-making processes (Nauwelaers and Wintjes, 2002; Nauwelaers, 2003; Andersson et al., 2004; Pietrobelli and Rabelotti, 2004; Chaminade and Edquist, 2007; EuropaInnova/ProInno, 2007). Local co-ordination is key, and through the participation of firms at local level, the idea is that policy will gain a better understanding of the problems at hand and of specific needs and local firms will get more adequate support (Bennet and McCoshan, 1993). National policy is too blunt to cope with the complexity and detail to reach these levels, but the national level should rather create conditions whereby firms, intermediary organisations and public organisations can engage in self-organised process of interactive learning (Cooke and Morgan, 1998). The current narrative is that the creation of innovations and new industries seems to be more complex today, and there is a greater need for incorporating more diverse knowledge bases and actors than previously, often also including global relations (Helmsing, 2001). It is therefore hard to set up specific goals and attain these through “engineering efforts”, or to find the best firms, projects or technologies by picking winners. There is greater uncertainty as regards what should be seen as the future industries and innovations. Thus, traditional top-down oriented planned approaches face difficulties in dealing with such uncertainty. In a complex and fast-moving world it is very hard to know who the winners are, when it comes to both firms and technology (Helmsing, 2001).

The cluster is from the beginning an analytical metaphor, but it has become such a strong phenomenon that it is considered to be a real entity by many and in particular within policy circles. The cluster provides means for analysing local relations, but also an entity to interact with or intervene in or for, as it contains a concentration of related actors that might be willing to participate in policy projects. The cluster can be seen as the ideal scope for the current trends of innovation policy that emphasise de-centralisation of decision making with deliberative processes in design and implementation of policy programmes (Borrás, 2003).

In clusters there is a concentration of a critical mass of actors that will have common interests in a number of issues, and where interests and returns are concentrated actors are more prone to organise themselves to exert pressure on governments and other economic actors to favour their special interest. The returns will come at the expense of broader groups which will have to bear costs that are spread relatively thin (Olson, 1965). Collective action can be geared towards creating advantages for participants, by securing markets and creating shared monopolistic profits for its members. By rigging markets, the cartel members will secure incomes for themselves and prevent newcomers from entering markets. With the establishment of a cartel and a secure market, the participants will not only prevent innovations from other actors, it will also reduce the incentives to innovate and create improved products for the cartel members, as the existing business model is secured. In the long term this will destroy the dynamics of the cluster. To uphold their position, incumbent actors can prevent newcomers by putting pressures on partners in distribution chains or suppliers not to interact with newcomers and in such a way prevent potential competitors from accessing key resources or from selling their offerings. These groups can also influence and acquire special status with government, and through different measures protect their position, such as local, national, environmental, social, moral etc. measures, and prevent the establishment of new firms or the development of new and competing technologies (Mokyr, 2002). It is dangerous for long-term perspectives of clusters if incumbent actors manage to influence innovation policy to focus more on existing incumbent resources, actors and technologies rather than potential future ones.

Cluster policies have been seen as a remedy against innovation policy being captured by vested interests, as happened with policies of picking winners, and instead providing broadly based public services that will benefit all firms in a cluster. However, this also means that cluster actors can influence the public to direct resources towards these incumbent actors and their technologies at the expense of emerging technologies that do not have the same established resources to voice their interests. Instead of picking firm winners, government will pick sectoral or industry winners.

There are also challenges connected to cognitive lock-in. The mechanisms that facilitate collaboration in clusters – the shared cognitive frameworks – are more conducive to incremental innovation than radical (Nooteboom, 2006). Radical innovations come out of combinations of knowledge bases

that are very different, and these knowledge bases are accompanied by cognitive frameworks that are far away. Furthermore, firms in clusters respond better to incremental changes in technology and market demand, but have fewer capabilities to meet significant changes, as they are often more stuck in traditional patterns and hold self-sufficient beliefs (Harrison and Glasmeier, 1997). Clusters can strengthen lock-in in a number of ways: i) functional lock-in, which is a situation where firms have too much invested in their current relations with suppliers and customers that makes it hard to break out of current operating patterns; ii) cognitive lock-in, when firms are locked into the current cognitive opportunities framework and do not survey beyond current market opportunities; iii) political lock-in, where an intensive and consensual political orientation locks a system in an inefficient route (Grabher, 1993).

2.3 Institutional Theory

2.3.1 Introduction to Institutional Theory

Researchers on innovation (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edqvist, 1997) emphasise that it does not come about in isolation, but in interaction between persons, within firms, but also between firms, and between firms and knowledge-exploring organisations such as universities and research institutes (Coenen, 2006). In order to understand how clusters can support innovation, one needs to explore how interaction takes place in clusters. In this thesis an institutional economist (North, 1991; Hodgson, 2006) approach has been chosen to analyse how institutions affect how interaction takes place in clusters and the effect on innovation. Institutions are social structures that enable interaction, through means such as language and financial systems, and constrain and focus social behaviour by providing rewards and punishments that give actors incentives to participate in exchange processes and to stick to previous commitments (North and Weingast, 1989; Rosenberg and Birdzell, 1986; Gunnarsson and Rojas, 1995). Institutions provide stability in a complex environment, as actors can better predict the behaviour of others (Hodgson, 1988).

The most renowned scholar as regards institutions is North, who defines institutions as rules of the game in a society, and organisations as the players of the game (1991). North along with others such as Coase and Williamson

make up the *new institutional economists*. They argue that the outcome of efficient markets, as described in neo-classical theory, can only happen when it is costless to transact (Coase (1960). However, as there are costs arising from legal procedures, political systems, educational systems, culture, etc., institutions matter, as is supported by empirical studies (Wallis and North, 1986). Transaction costs will also affect the amount of exchange in an economy and how organisation takes place, e.g. if an organisation will retain resources internally, or if there will be outsourcing and external collaboration, which affects the possibilities for specialisation (North, 2005). The new institutional economists differ from the *old institutional economists*, in that they are more theory-oriented and are methodological individualists. The old Institutionalists (Commons, 1934; Veblen, 1899, 1909) were oriented to methodological collectivism and not theory. Their prime concern was with describing the economy, the distribution and role of power in deciding who will govern economic structure. Important topics were legal rights and constraints of the economy. Legal codes reflected mainly existing elites' desires and market equilibriums did not have desirable social characteristics *per se*.

In this thesis, methodological interactionism will be followed, which is a middle way between the schools mentioned above that have been described as under- and over-socialised perspectives (Hodgson, 2006; Hollingsworth, 2000). This perspective connects institutional micro fundamentals with a macro perspective, which will benefit the analysis in connecting clusters, institutions and innovation. Institutions are social structures and are defined as “*systems of established and prevalent social rules that structure social interactions. Language, money, law, systems of weights and measures, table manners, and firms (and other organisations) are thus all institutions*” (Hodgson, 2006). This provides a richer and more complex view of how institutions function than in New Institutionalism, which is beneficial for cluster analysis with a focus on the inter-organisational level. Still it does not fall into methodological collectivism like the old Institutionalists, with an over-emphasis on socialisation of individuals, lock-in and path-dependency. In the over-socialised approach it is hard to explain institutional change, but “*individuals are embedded in a complex institutional environment and that institutions not only constrain but also shape individuals. Of course, institutions are formed and changed by individuals, just as individuals are shaped and constrained by institutions*” (Hodgson, 2006).

Behaviour is guided by rules and norms that are socially transmitted. Individuals engage in rule-like behaviours, through the psychological mechanism of habituation. A habit is a disposition to act, think and perceive things in certain ways, triggered by an appropriate stimulus or context. For the habit to become a rule, it will need to incorporate some type of normative content, to be potentially codifiable and spread in a group. Habits give institutions durability, power and normative authority. Institutions depend upon individuals for their existence; at the same time, all individuals are born into a world of pre-existing institutions, which will confront and form the individual. They structure, constrain and enable capabilities and behaviour of agents, and can also change the incentives and aspirations of actors. These institutions reside in the dispositions of other individuals and depend on the interaction between them. Institutions are both objective structures out there and subjective as they reside in the individuals. Still individuals are not locked completely into structures, but there is individual agency with incentives to alter structures and institutions. Actually, if there was no agency, it would be hard to explain how the individual appropriates social structures from the beginning (Hodgson, 2007). Institutions are formed through deliberation bottom-up through negotiations between actors, but they also have top-down effects on individual behaviours (Hodgson, 2006).

Institutions are often connected to some kind of power, and it is through this that institutions exist. If the powers cease to exist the institutions will fade away, and the same happens if institutions are not exercised. At the same time, laws will not automatically become rules that individuals follow. Legal systems rely on informal rules and norms, and if they do not incorporate the needs and reality of practices of people, or are too complex or costly, many will abstain from participating in the formal economy (De Soto, 1988, 2000). However, acting in informal markets hampers possibilities, as a number of conducive institutions are absent, such as insurance, using property to raise capital, contract enforcement through courts; there will thus be problems for firms to grow, as these entrepreneurs need to avoid government detection (De Soto, 1988).

The particular focus in this thesis is on the role of institutional arrangements (Hollingsworth, 2001; Amable, 2001; Nooteboom, 2002; Nooteboom, 2006) and how these affect cluster externalities and their influence on innovation. Before proceeding to a description of institutional arrangements

and their connection to innovation, a short discussion of how to carry out institutional analysis is required.

2.3.2 Institutional Analysis

Institutional analysis can help us understand how human interaction takes place, what kind of incentives stimulate certain kinds of activities to take place and prevent other types. The point of departure in this thesis is Hollingsworth's (2000) framework for carrying out institutional analysis. He distinguishes between four levels of institutions that are of interest for analysing how institutions affect innovativeness, and as a complement there is an outcome category for measuring output and performance. His categories for institutional analysis are: i) institutions, ii) institutional arrangements, iii) institutional sectors, iv) organisations and v) outcome. These are briefly outlined in Table 2. The focus in this thesis is on the relation between institutional arrangements and innovativeness in clusters. However, the four institutional levels are related, so before proceeding to the more in-depth description of institutional arrangements, an introduction to institutions, sectors, and organisations will be provided.

The first level of analysis is institutions, which include formal and informal rules, laws, norms, values and habits. This is the fundamental level and has the greatest influence on the other levels of analysis, as institutions shape and reflect the actors' values and preferences, which in turn guide the behaviour of the actors. This affects who and what is included in decision-making processes, how information is gathered, processed and structured. There are different systems for different situations, such as families, professional situations, leisure time, and in different cultural contexts. There also appear to be higher-order rule systems such as meta-rules or norms that include lesser rule systems, and these meta-rules work as arbitration between the lesser rule systems. Societies differ in the set-up of institutions, with varying degrees of autonomy, and the scope of possible actions for individuals, which will affect the possibilities for societal change.

Institutions and institutional arrangements, which are the mechanisms for co-ordination of actors' transactions, affect the performance of different economic sectors of a society, as well as the performance of the total society. The institutional framework is different for different sectors of societies, and it can be worthwhile to explore the different sectors of a society and their relation to innovation. Examples of institutional sectors include the system

of education, the system of research, business systems, financial markets, legal systems and the state. Each of these sectors has some autonomy and goals which can be contradictory of other institutional sectors with which it is connected.

Table 2: Components of institutional analysis

Level of analysis		Components
1	Institutions	norms, rules, conventions, habits and values
2	Institutional arrangements	markets, states, corporate hierarchies, networks, associations, communities
3	Institutional sectors	financial system, system of education, business system, system of research
4	Organisations	Firms, public authorities, associations, trade unions, NGOs.
5	Outputs & performance	statutes; administrative decisions, the nature, quantity and the quality of industrial products; sectoral and societal performance

Source: Adapted from Hollingsworth, 2000 (list of authors removed, and examples of organisations are added).

Note: The five components in this table are arranged in descending order of permanence and stability. That is, norms, conventions, etc. are more enduring and persistent than each of the other components of institutional analysis. Each component is interrelated with every other component, and changes in one are highly likely to have some effect in bringing about change in each of the other components.

Institutional rules, norms and conventions also evolve in tandem with organisational structures. Fiscal, political, judicial and other regulatory norms limit and shape the culture and structure of organisational behaviour. Norms influence the behaviour of organisations which will vary between countries, and influence the patterns of ownership and relations with suppliers and customers. Still the behaviour between organisations within a country or institutional configuration will vary, but there are a set of cultural and structural characteristics which distinguish German firms and universities from those in America. Some societies have multiple institutional environments and there is heterogeneity in terms of what constitutes appropriate behaviour of organisations.

When making an institutional analysis it is of interest to observe the performance of the system and the outcome of processes. This is something

that varies between the objects of study; if it is a study of the legal system, the output may be court rulings and for the business sector it can be new products. By analysis of this level one can observe how well the other arrangements are operating, how well they support innovation. It can also serve as a basis to analyse what kind of output is generated, if it is more supportive of incremental or radical innovations, more products or services, or new processes, or if the innovations lead to economic growth or not.

2.3.3 Institutional Arrangements

Clusters are not governed by one form of mechanisms, nor is interaction governed by one form of institutional arrangements, and in most clusters there is a wide array of institutional arrangements in place that govern the relations between actors. Institutional arrangements are the independent variable of my analysis, and will be described in depth in this section, in particular with the relation to clusters and innovation. Cluster externalities as described in the literature will not always appear in all clusters; it depends on the institutional framework. For example, a country with very rigid labour laws, with too strict regulation of labour market relations, may not have a vibrant labour pool with efficient labour market matching, as is commonly attributed to a cluster. Similarly, it may not be possible in all countries to develop collaborative associations between firms, research institutes and the public sector to jointly enhance the interest of a cluster, if there are strong antitrust laws. An important variable here is the institutional arrangements in place; how are relations between actors managed, what kind of mechanisms to facilitate transactions and what incentives and punishments are there to make actors stick to the process?

Institutional arrangements are the mechanisms that co-ordinate transactions. Hollingsworth (2000) has created a typology of the most important arrangements, markets, hierarchies, networks, associations, the state, communities and clans. Transactions and actors are not co-ordinated or governed by a single type of institutional arrangement, and each of these arrangements is differently organised in different societies. In societies the mode or modes of co-ordination that are dominant can vary and affect and influence how the other modes operate and how they influence its style of innovation, e.g. the strong role of the state in the Soviet Union and its influence on markets and associations.

Hollingsworth (2000) has distinguished institutional arrangements between what kind of motives drive the behaviour of actors in the arrangement, either self-interest or social obligations and the balance of power between actors, with a continuum between relatively equal agents interacting (the one extreme a well organized spot market) and inequality in power with strict hierarchies.

Market-based transaction as close to spot market activities, where products and services are well defined, obligations and rights between seller and buyer are likewise well defined. Actors respond to supply and demand, and this responds to temporary equilibriums, similar to neo-classic economic predictions. The organization of relations is relatively easy, as behaviour is standardised and sanctions for misbehaviour are standardised and guaranteed by state enforcement. The managing of relations in market transactions will not be able to provide collective goods or deal with externalities and will prove inadequate for monitoring technical change and innovation.

Still driven by self-interest, but with vertical power relations is the organization of a firm. Transactions will be organised within a firm, when transaction costs involved with managing relations outside of a hierarchy are too high (Coase, 1960, 1981; Williamson, 1985, 1999). The focus of this thesis, however, is on external relations and therefore this category will not be used in the analysis.

Then there are arrangements that are mixes of self-interest and social obligations, such as networks and associations. These can to different degrees include independence and equality between actors. Networks are looser arrangements that can be both informally and formally arranged, with specific purposes, with membership and meetings. When they become more formal they start to resemble associations. Associations are more formal organizations and these tend to co-ordinate economic activity among actors engaged in the same or similar kinds of activities. Associations are organizations based on voluntary membership, where members can be individuals or other organisations. In the association there are multiple exchanges between members. They are instituted to carry out specific activities or to protect the interest of their members. They can co-ordinate activities that are outside of market arrangements, to resolve disputes, to be the entity that as a third party actor holds hostages that have been provided

during a process. They can manage wage or price negotiations and provide collective benefits, such as education and training programmes or R&D activities.

Communities and clans are institutional arrangements built upon trust (mainly in the form of bonding social capital, which is based on ethnicity, religion, and other group cultures), reciprocity or obligation, and not proceeding from individual isolated motives. These arrangements can facilitate processes by reducing costs involved in transactions, but can also, through obligations and expectations, reduce the scope for innovation and renewal and strengthen inertia.

The final arrangement is the state. It is unique in that it has power to sanction and regulate the various other arrangements. It is also nominally the one with the monopoly of violence and the ultimate enforcer of rules and various mechanisms. It defines property rights and manipulates fiscal and monetary policy. It has powerful tools to influence the incentive systems of the society (Johnson, 1992: 40). The state can also be an economic actor by engaging directly in the production of goods and services and exchange relations. Hollingsworth (2000) has identified a number of challenges connected with the state mechanism: i) there is a need of control external to state bureaucracy (judges, parliament, market) to protect against state abuses; ii) lobbies can capture public interest goals and gear it towards the narrow interest of small groups of vested interests; iii) the state can address public goods problems, but there is a history of problems in providing them in precise amounts; iv) there is a history of highly bureaucratic and cost-inefficient production through state solutions; and finally v) the state can have problems in inducing technical change.

Table 3 presents Hollingsworth's view of how the different institutional arrangements are structured, how exchange takes place and what the individual and collective means of compliance are.

These different types of arrangements can vary between different countries and settings, depending on to what degree they are embedded in the social structures where they take place. Actors are not co-ordinated or governed by a single type of institutional arrangement, however, and the degree of presence or mix of arrangements varies between societies (Hollingsworth, 2000). The mode of co-ordination that is dominant varies, influencing how the other modes operate and affecting which styles of innovation will occur.

Table 3: Logics of institutional arrangements

Co-ordination mechanisms	Organizational structure	Rules of exchange	Individual means of compliance	Collective means of compliance
Markets	Easy entry and exit Bilateral exchange or market site (Wall Street)	Voluntary spot exchange	Legal enforcement of control Regulations to enforce contracts	Norm of private property. Legitimacy of market mentality
Communities	Informal membership evolves over a long time	Voluntary exchange based on social solidarity and high degree of trust	Social norms and moral principles impose obligations Knowledge of others and reciprocity over time	Highly institutionalized norms and rules require members to accept 'corporate' obligations
Networks	Semi-formal membership Bilateral or multilateral exchange	Voluntary exchange over a time period	Contractual bonds Resource dependence	Personal relations Trust built outside the economic arena
Associations	Formal membership Multilateral exchange	Restricted to members Emphasis on insider/ outsider or we/they mentality	Self-interest Reputation effects	Some degree of compulsion Private interest type of governance
Private hierarchies	Complex organizations which tend to become bureaucratic hierarchies	Restricted to members, exchange based on asymmetric power, bureaucratic rules	Rewards to individuals Asymmetric power, threat of sanctions	Highly institutionalized rules Members socialized into corporate culture, use of sanctions
State	Public hierarchy De jure and imposed membership	Unilateral action Indirect political and economic exchange	Exit, voice (vote, lobbying), loyalty	Coercion Norms and public rules

Source: Hollingsworth (2000)

2.3.4 Arrangements, Clusters and Innovation – the Research Gap

In the review of the literature I have not found any specific description of how differences in institutional arrangements affect how clusters have an impact on innovation. There is literature discussing related areas, such as

governance of clusters; relation between one form of arrangement and innovation; relation between cluster governance and effectiveness of transactions and literature on institutional arrangements and innovation.

Porter (1998) is not consistent about the institutional frameworks of clusters, but describes clusters both as places with a presence of multiple arrangements and on occasion uses the term cluster to describe an agglomeration or a locally anchored business network. He states that arrangements are important for innovation, but does not say how different arrangements have an impact on innovation.

There are authors that describe clusters as an institutional arrangement in itself that arises from repeated collaboration and local culture. The arrangement consists of other organisations and practices that reduce transaction costs and enable collaboration (Visser and De Langen, 2006). Others focus on how the presence of social relations and social capital in clusters strengthens transactions not only between private actors (Scott, 1988, 1992; Nooteboom, 2006), but also between private and public actors (Helmsing, 2001). There are also researchers who focus on the role of collective action for innovation and argue that in clusters there are social practices that reduce transaction costs and create opportunities for learning and innovation, as they provide means for co-ordination of activities beyond price and regulation (Malmberg and Maskell, 1999, 2006). However, in this literature it is mainly the view that clusters are a particular form of institutional arrangement, or that in clusters there is one form of institutional arrangement (community-based) that supports innovation activities.

There are authors who have explored how institutional arrangements of global value chains affect the possibilities for small firms in clusters to trade and upgrade (Gereffi, 1994; Humphrey and Schmitz, 2000; Guilianì et al., 2005a; Pietrobelli and Rabelotti, 2004; Chaminade and Vang-Lauridsen, 2008). In this literature, three types of mechanisms are commonly described: i) market relations or arm's-length relations, ii) networks, joint action and relations on a equal footing, iii) quasi hierarchies, where some firms are subordinate to others, even though they are legally independent firms. The authors, however, did not explore differences in institutional arrangements in the local relations, even though they are there implicitly.

There are authors who have addressed differences in the institutional set-up by describing types of actors, dominant forms of relations and governance mechanisms and what type of outcomes of efficiency and innovation to expect (Markusen, 1996; Altenburg and Meyer-Stamer, 1999; McCormick, 1999; Parrilli and Sacchetti, 2006).

Of particular interest was De Langen's (2004) framework for analysing the performance of cluster governance. The focus is on the governance of clusters and on the possibilities for collaborative action to address joint challenges and opportunities. The framework includes six general modes of co-ordination of transactions in clusters: markets, firms, inter-firm alliances, associations, public-private organizations and public organizations. Together they form a cluster governance regime. Different clusters do not have the same mix, or governance regimes or capabilities available to them. The performance of the governance regime depends on how well it lowers transaction costs and enables co-ordination of activities. There are four influential factors for this: trust, leader firms, knowledge intermediaries and collective action regimes. *Trust* reduces transaction costs and facilitates co-operation, especially in cases where opportunity control mechanisms and incentive control mechanisms are insufficient. *Leader firms* are not connected to firm size, but their role in the cluster. These are firms that have abilities and incentives to assume leadership, and make investments with positive external effects for co-located firms. *Knowledge intermediaries* are specialised R&D institutes, training centres, consultants, information brokers, or business associations that provide strategic insights, facilitate upgrading of firm capabilities, stimulate joint action, provide information or act as brokers. *Collective action problems* are wider than what the interaction between a limited number of firms can solve. To manage these problems, especially when it is of free rider character, then there can be a need for non-market co-ordination (Olson, 1971). The presence of trust, leader firms, and knowledge intermediaries can help in addressing CAPs and it can lead to the creation of *collective action regimes* to resolve the problems. These regimes can be created through different types of arrangements, but most often through associations, public-private partnerships or state arrangements. De Langen's view of cluster governance is interesting, as he does not say that in clusters there is only one type of governance or that it has to be a certain type of governance for it to be a cluster.

However, my interest is in how different arrangements influence cluster externalities and the impact of this on innovation. I do not agree with the view of a cluster as a specific form of governance, or that clusters always are learning regions with common operating procedures among actors. This may be very common, but not always present. Clusters also differ with regard to which kinds of institutional arrangements are present, as some may dominate in some clusters, whereas it may be different in another cluster. There is some literature on cluster governance, but this literature seems rather to combine different institutional arrangements and framework in order to be able to identify one integrated governance regime, rather than to explore the role of different independent arrangements.

2.4 Institutional Arrangements of the Analysis

When choosing and defining the categories of institutional arrangements, the point of departure was Hollingsworth's (2000) framework for institutional analysis of innovation. However, these categories have been altered due to findings in the literature on clusters, and also due to influence from my empirical material. The category of hierarchies was removed as this is a study of inter-organisational transactions.

In an empirical study of 160 actors from clusters in Americas, Europe, Australasia and Africa, where one question was which are the dominant relations in clusters the answer was that long-term relationships were by far the most common, followed by short-term coalitions, hierarchy, spot market, and further down family and ethnically based transactions (Enright, 2000). Also, initial review of my empirical material indicated that community arrangements mattered little. As a result, I merged networks, associations and on a few occasions I discuss some community concerns in relation to this category. The reason is that these categories are very similar and are dependent on related mechanisms for upholding them, and involve a feature of trust based on repeated interaction, so-called bridging social capital (Putnam et al., 1993; Coleman, 1988), and community arrangements are based on what is called bonding social capital, which originates from cultural structures such as religion and ethnicity.

Table 4: Summary of the institutional arrangements

	Description	Enforcement and influence	Incentives
Market	A voluntary exchange where relations are kept at arm's length. Strict regulation of behaviour and exchange. In pure spot markets, it is relatively easy entry and exit.	Use of contracts, standards, and state enforcement of contracts.	Market selection with pressure to survive. Strong incentives to deliver what customers demand, otherwise an organisation will be forced out of the market.
Network	Looser arrangements with independence and equality between actors. Interaction is based on trust. Trust comes from repeated interaction, bridging social capital. Networks can have specific purposes. Can be of formal or informal character.	Threats of exclusion and an end to future collaboration. Can have contracts to regulate interaction. Associations are governed by the voice of members. Community relations "monitored" by norms, and members risk exclusion.	Rewards are access to knowledge, markets and resources
Quasi hierarchy	Based on voluntary exchange, but the relations are asymmetrical in power. These are a combination of self-interest and vertical relations; often there are supply chain management relations.	There are contracts, but also an implicit threat of losing a vital customer.. Loss of vital customer and market access.	The weaker actor can gain access to markets, knowledge and long-term incomes. Dominant firms can increase flexibility, reduce risk and improve possibilities for acquiring new innovations.
State	A public hierarchy, which every citizen is a member of <i>de jure</i> . The state can carry out unilateral action and multilateral exchange. It has power to sanction and regulate the other arrangements. The public can use legislation, influence norms of society, can create organisations for production of goods and services and intermediation.	The state has the monopoly of violence and is the ultimate enforcer of rules and various mechanisms. Influence comes through voice, by voting or lobbying.	It defines property rights and manipulates fiscal and monetary policy. It provides moral and fiscal incentives, but can also use brute force to make people alter behaviour.

Furthermore, due to observations that the set-up of clusters differs with regard to the size and activity of firms in the cluster and with the relative strength in relations (Markusen, 1996; Enright, 2000), the observation of the role of leader firms in clusters (Albino et al., 1999; De Langen, 2004) and the literature on global value chains that explored uneven power

relations (Gereffi, 1994; Pietrobelli and Rabelotti; 2004), the category of quasi hierarchies has been added. The result is four analytical categories of institutional arrangements with differences in how interactions are enabled, by incentives and enforcement, as shown in Table 4.

In the following sections these categories will be described in more depth. These are ideal types, while in reality these vary between different countries and social contexts. Furthermore, actors are not co-ordinated or governed by a single type of institutional arrangement, and the degree of presence or mix of arrangements varies between societies (Hollingsworth, 2000). There can be institutional arrangements that dominate other arrangements and how these operate and which styles of innovation will occur. In the last section of this chapter there will be a discussion of how the interplay of arrangements has an impact.

2.4.1 Market Arrangements

Market arrangements are voluntary exchanges between actors that take place through arm's-length relations. They are regulated either by contracts, standards or state regulations that describe obligations and rights between seller and buyer, and also what characteristics to expect of products and services. The degree to which markets are standardised is often dependent upon the complexity of transactions, and also the size of a market and where in the life cycle it is. Newer markets have less well established practices, whereas markets for commodities are highly standardised in so-called spot markets. Depending on standardisation, it is relatively easy for actors to switch between products and services (De Langen, 2004). Actors respond to supply and demand and this responds to temporary equilibriums, similar to neo-classical economic predictions (Hollingsworth, 2000).

Market relations are most often enforced by state authorities, but there are also settlements by arbitration that are handled by contracts and intermediaries, such as network organisations like chambers of commerce. These latter types of arrangements are facilitated by network and community effects where actors want to build a reputation and maintain trust.

There is a pressure for firms to generate offerings that are bought by customers, otherwise they will be driven into bankruptcy. In this process it is imperative to regenerate their products and services over time; otherwise a

competitor will force the firm out of market (Schumpeter, 1934). There is also a pressure on organisations to be effective and match costs and incomes, otherwise they will be forced out of the market.

Market transactions will not only create pressure on firms and their relation with suppliers and customers for efficiency and upgrading, but will also generate an effect of overall efficiency on an economy-wide level. In market-based relations there will be a generation of information signals through the prices that actors pay each other in the network of market relations. These price signals provide information about how to allocate resources in an economy, where rising prices will generate an influx of new actors willing to provide more offerings, and more resources will be directed to the area of rising demand; likewise where there is a drop in demand and an oversupply there will not be more resources diverted and actors will be forced out of business. There are millions of decisions that are taken in parallel and the outcome of their decisions and the relevant information are transmitted through price signals to the other actors in the system; this is Adam Smith's (1776) so-called invisible hand that brings a measure of co-ordination and allocates resources in an economy without central co-ordination.

Market-based transactions are inadequate for monitoring technical change and innovation (De Langen, 2004). It is complicated to collaborate on innovation projects, with nothing but a purely contract-based relation, as radical innovations are uncertain processes; where actors do not know the outcomes of processes in advance; where market potentials are; which resources need to be involved; time frames or costs. Therefore it is complicated to base relations only on contracts, and it is a costly process to negotiate and set up relations in dividing rights of outcome, who will provide resources and in what time, etc.

There are also problems in creating innovations that manage negative externalities, such as environmental costs, where polluters can be said to have been subsidised, as they have polluted their environment and not borne the costs that they have inflicted upon others. However, market-based actors will in most cases not voluntarily take these costs upon themselves, and it is a very difficult process to estimate what the real costs are. There are also challenges with regard to public goods, such as investment in education and research that can benefit many, but with the individual cost being higher

than the societal benefit, and there will therefore be an under-investment in public goods (Arrow, 1962).

2.4.2 Network Arrangements

The category of networks in this thesis consists of what has been described elsewhere as networks, associations and to some extent communities (Hollingsworth, 2000) and public-private partnerships and inter-firm alliances (De Langen, 2004).

Networks are looser arrangements with multiple multilateral voluntary exchanges that can be both informally and formally arranged, with specific purposes, with membership and meetings, where they start to resemble associations; or communities of practice where actors with common interests meet and exchange experiences. The common bases for the arrangements is that they build on trust relations that develop either through repeated interaction, so-called bridging social capital (Putnam et al., 1993; Coleman, 1988), or from bonding social capital that originates from culture and norms that have evolved over long periods of time, e.g. based on ethnicity, families, clans, religion. The repeated interaction also leads to the establishment of practices of proper conduct, which facilitate interaction and can be complementary to contracts.

Network arrangements and in particular in the form of associations are useful for establishing standards and means to secure quality assurances of actors, by establishing norms, standards, best practices and codes of conduct. They can help bridging trust, by indicating to others whom to interact with, and indicating who has behaved properly previously. They can co-ordinate activities that are outside of market arrangements, to resolve disputes, to be the entity that as a third party actor holds hostages that have been provided during a process. They can manage wage or price negotiations and provide collective goods, such as training programmes or R&D activities. Furthermore, in many places they offer business services, such as help with understanding legislation or services for handling legislative requirements such as taxes. They are influenced by voice or by member exits.

Unlike communities, networks do not take social considerations into account, but are more professionally oriented and their borders are not as distinct as in associations or in communities. There are limited enforcement

mechanisms in the network itself, they are based on keeping reputation, and ways to influence it are based on exit and voice.

Members often have a self-interest to comply with membership rules, as they expect benefits from membership, such as complementary knowledge, markets and resources, and they do not want to have a bad reputation, as this would lead to exclusion. Furthermore, networks provide actors with mechanisms to address common problems, such as influencing the establishment of training facilities, the creation of infrastructure, attraction of labour, creation of standards, etc.

Networks can also enable collaboration such as in innovation projects. Networks reduce transaction costs through the lesser need for detailed contracts, as regulation of behaviour is managed by the trust that is built up in the network. Furthermore, it enables collaboration through the establishment of working practices and reduces cognitive distances (Nooteboom, 1999, 2000).

Networks can provide possibilities to speed up the development of new products and services by combining capabilities with other actors. It can also provide more flexibility to more easily adapt to technological and market changes. Through networks firms can take part in more projects than they could have developed by themselves, in this way they can more easily stop some projects and pursue others, in response to changes. Through networks there are greater possibilities to influence the outcome of standardisation processes; in a more inter-operable and inter-connected world, standards are becoming ever more important. It is not always the best systems that will win, but the ones that are best positioned for the leading actors. Single firms, however, do not have the power to create standards themselves and need to collaborate with other actors, such as firms and standard-setting authorities and organisations, to create standards (Bengtsson et al., 1998).

As a response to increased complexity, networks where private and public actors join in deliberative processes have become increasingly popular (Helmsing, 2001). Industry representatives, either as individual organisations or through representative associations, take part in processes where there is a need for industry voices and actors to participate in implementing the new public-private projects. Cluster initiatives belong to this category of transaction, incorporating private and public actors, and often representatives of academia. These are efforts that often involve a

broad range of actors that collaborate to achieve specific or common goals in order to strengthen the competitiveness of the cluster actors, or at least the members of the initiative that are most often co-located.

There is a danger that networks run into cartels and facilitate monopoly behaviour. Networks can use their influence to prevent newcomers and new technologies from entering markets, and they can also lobby governments to implement state arrangements to protect their interests or divert resources to the cartel, through arrangements with prices and disturbed procurement processes in order to facilitate that certain firms take turns in winning contracts, while keeping up price levels. As argued already by Adam Smith (1776), *“People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices.”* These types of activities will hamper innovation, both by preventing new technologies from entering markets, but also due to reduced pressures among incumbents to create innovations, as their existing business model is secured.

2.4.3 Quasi Hierarchy Arrangements

Quasi hierarchies are relationships between legally independent firms in which one is subordinate to the other, with a dominant actor that defines rules that weaker actors have to comply with. These rules can be formalised to different degrees in contracts, but relations can also be based on trust and repeated interaction. Typical transactions involve supply chain management, and to some extent franchising and licensing. The relation and the influence of the dominant actor come from the asymmetry in power, knowledge, resource and access to markets. There can be contracts, but the relation is also enforced through the implicit threat of losing a vital customer and partner, without which the firm may not survive. In more severe cases dominant firms may force weaker actors to comply by threatening to block them from market entrance by influencing other actors in their network.

The relation is a combination of self-interest and vertical relations, where the dominant actor provides access to world markets, knowledge and long-term incomes of an important degree for the weaker party. As an example TSMC, the Taiwanese chip firm that was at the base for the growth of the microchip industry in Taiwan, benefited immensely from the establishment of Philips in Taiwan, which helped in developing that industry in Taiwan, by purchasing their products long-term (Shih, 2009). They can provide

knowledge and educate the suppliers and thereby upgrade them, but also benefit from spill-over of knowledge developed in a dominant firm (De Langen, 2004). In a developing country context, leader firms can act as gatekeepers with high degrees of absorptive capacity who can bring in new and competitive knowledge to local supplier firms (Guiliani, 2005). Furthermore, through their influence they can pressure suppliers to implement new technologies, and thereby stimulate upgrading.

For large firms, collaboration with smaller actors can be a way of increasing flexibility, managing risk, and a possibility for acquiring new innovations. Firms seek flexibility to meet a changing environment by developing their core competences (Prahalad and Hamel, 1990) and not locking resources into factories, R&D organisations and market organisations, but rather renting resources (Bengtsson et al., 1998). By focusing on core competencies, firms will use their capabilities more efficiently, and also with the aim of keeping these resources internal through learning by doing, the capabilities will develop even further. For the powerful actor, interacting with smaller suppliers is sometimes a means to create innovation without disturbing internal processes. The size of an organisation influence the speed with which an organisation responds to changes in the environment, large firms will often respond more slowly to change, due to established routines and established buffers of resources. Many large firms are better equipped for incremental innovation, where there is stepwise perfection of offerings. Smaller firms can be better fitted to respond to changes; as they have fewer resources linked in to specific routines and knowledge bases, it can be easier to change track. However, the smaller firm has fewer reserves to carry out change. Many firms have also started to seek external collaboration as a way of reducing risks, as the costs of not finding the right offer or missing the right standard are too dear for a large firm (Chesbrough, 2003).

However, there are also dangers for the weaker firm, which can end up in a position where another firm has power over one's firm to the degree that the firm is totally dependent on the stronger party, which will also have control of the firm's future (Bengtsson et al., 1998). So it is a long-term interest for most actors to deploy strategies to diversify into avoiding dependence from the more powerful actor. The dominant actor can pressure the weaker actor to implement processes that fit the dominant actor and restrict what kind of activities the weaker part can carry out and which partners they can have. This locks in the weaker actor and reduces its possibilities for more radical

innovation. At the same time, it was more radical innovation that made the dominant firm interested from the beginning; see for example open innovation relations where large firms in the medicine business collaborate with smaller firm and incorporate technology pieces from external actors into their business models (Cunningham, 2002; Quere, 2003; Gassman and Reepmeyer, 2005).

2.4.4 State Arrangements

The state is the most complex co-ordination mechanism, it is an organisation, and it can create new organisations to handle interaction and produce services. Furthermore, it can create laws and regulation that can force members to change their actions through the enforcement mechanisms of legal and police system. All citizens are compulsory members, and in almost all states of the world the state has the monopoly of violence through which it can force citizens to comply with rules and legislation (Hollingsworth, 2000). Besides the creation of new organisations or regulation, it often also tries to change and influence people's behaviour and influences the norms of society through educational/informational activities. It also works with different kinds of incentive schemes to influence people's behaviour, such as provision of resources, subsidies or tax reductions connected to specific desired behaviours. It upholds systems for property rights and rules for exchange. In most countries the way to influence is through voice, by voting or lobbying; in extreme cases people also break relations by exit and leave countries or use violence in order to force the state to change policies. Through state arrangements there are powerful tools to influence the incentive systems of the society. It defines property rights and can manipulate fiscal and monetary policy that can provide important incentives to stimulate certain behaviour.

The state is the actor that has the greatest possibilities in a society to amass resources and means to enforce actors to comply with decisions and influence certain kinds of behaviour. It is in a position to overcome problems of free riding, by making it compulsory for actors to participate in schemes; it can break lock-ins by introducing new operating mechanisms and new technologies.

Of particular interest for this thesis are activities related to innovation and cluster policies. Innovation policies include a number of approaches to alter the economic playing field, through changes in the institutional framework

(such as intellectual property systems), procurement programmes, or by changing factor supply through education programmes and R&D centres. The ambition can be to influence actors to change behaviour, or to raise capabilities by educational programmes or to raise capacity by building infrastructure. Through regulation there is also a possibility to change the innovative output; in discussion about new clean tech innovations it is often suggested that there is a need for regulation to create certain standards that can stimulate the outcome of new clean tech innovations that would not occur without regulation (Porter, 2008a). The public authorities can strengthen or change the direction of existing organisations, but it can also create new organisations, such as R&D institutes or intermediaries that link actors. Organisations for SME and innovation support have lately become popular; these are in charge of providing services for business start-up, business development, provision of venture capital, and as in the case of incubators, access to cheap office space and networks with other entrepreneurs and people with management and technology skills (Helmsing, 2001). Through programmes of social security, resistance to innovation can be decreased as groups standing to lose from the implementation have less to fear and are enabled to alter capabilities and move to other sectors. Furthermore, they may not block the introduction of innovations (Edquist, 1985). Finally, despite improved transparency in recent years in procurement practices, there are still problems with corruption in many countries. Still, the public sector is an actor that procures huge amounts of goods and services every year, even if this takes place in a country with a minimal state. These purchases can be used to stimulate innovation and upgrading in clusters (Rolfstam, 2008).

Cluster policies are policies geared towards clusters, and these policies have increased in the last decade (Nauwelaers and Wintjes, 2002). Policymakers have become attracted by clusters, not only because of an attractive vision of a possible future, but also because in many regions these represent the most important industries and policymakers are exploring new means for stimulating their industries. In the literature on clusters there is a strong connection to policy. The cluster can be seen as the ideal arena for the current trends of innovation policy; these trends emphasise de-centralisation of decision making, interaction between policymakers, academia and firms, and deliberative processes in design and implementation of policy programmes (Helmsing, 2001; Mytelka, 1991, 2000; Pietrobelli, 2007;

UNCTAD, 1998; Vavakova, 1988, 1995). The cluster provides means for analysing local relations, but also an entity to interact with or intervene in or for, as it contains a concentration of related stakeholders that might be willing to participate in policy projects in a delimited geographic area, which quite often matches political decision areas.

The cluster can be an optimal arena for policy to support transactions in reducing costs and enabling collaboration that leads to innovation. The presence of a critical mass of actors improves opportunities to share and reduce costs per participant or person affected by policy intervention. The return on investment becomes better as there are more beneficiaries from interventions, such as infrastructure and R&D institutes. There is an increased focus on local co-ordination with participation of local firms that hold specialised knowledge, which is supposed to lead to better understanding of the problems at hand and specific needs and with better outcome of policy (Bennet and McCoshan, 1993). It becomes easier to tailor research and educational programmes to one industry need, and it will be easier for students to find employment; but there is also a greater number of actors who will potentially participate in interactive policy programmes, and sometimes an urge from actors that will influence policy to carry out activities in these locations on behalf of these industries.

Cluster policy is, like the cluster concept itself, vague and broad. It involves activities to strengthen interlinkages between actors, often in the form of initiation of cluster initiatives, but also policies to address negative externalities or facilitate positive ones, or to manage other framework conditions for firms in a cluster. Cluster policy often includes activities that have previously been seen as beyond the mandate of general public policy (Morgan, 1997; Storper, 1995). Europa Innova/ProInno (2007) made an analysis and overview of cluster support in Europe, and base their data of cluster policies on surveys from the Inno-Policy trend chart and ERAWATCH; at the time of the report they had registered 130 different policy initiatives on the national level alone in Europe, besides which there are numerous regional initiatives. They separate policy measures according to six objectives: i) human resource upgrading, ii) cluster expansion, iii) business development, iv) commercial collaboration, v) R&D and innovation and vi) business environment. These are then connected to eight categories of activities that policymakers undertake: i) information and contact brokerage, ii) practical assistance and advice, iii) direct financing and

facilities, iv) events and training, v) networking and organising events, vi) lobbying, vii) marketing and viii) monitoring and reporting.

There are not only possibilities with state arrangements, but also a number of challenges associated with the mechanism: i) there is a need of control external to state bureaucracy (judges, parliament, market) to protect against state abuses; ii) lobbies can capture public interest goals and gear them towards their narrow interest; iii) the state can address public goods problems, but there is a history of problems with providing them in precise amounts; iv) similarly, there is a history of highly bureaucratic and cost-inefficient production through state solutions; v) the state can have problems inducing technical change; in industries and activities with a domination of state activities there has been a tendency to a lower degree of innovation and inefficiencies in production, where – as in all-encompassing hierarchies – there are resources which are underutilised and there is not enough pressure to innovate in different sub-groups (Hollingsworth, 2000); vi) furthermore, it is a complex mechanism, which aggregates many activities and desires, and the means to influence the state is by exit, voice (vote or lobbying), which sometimes is a very blunt or tedious process.

There is a great challenge for policymakers on how to operationalise the cluster concept, as it gives no sharp guidelines for how to delimit a cluster. There have been models for statistical identification of clusters, looking at the concentration of related industries in regional contexts. Still many policymakers are using more loose ad hoc means of identification, choosing clusters from personal experiences of what are the relevant clusters to engage with, or altering previous business network programmes into cluster programmes. Others address a notable local industry, a distressed industry, or initiate a desired future-oriented industry, such as Nano or Bio-Tech, for which there is no solid foundation in the region. The latter projects are something that Enright (2000) has called wishful thinking clusters.

2.4.5 Interplay of Institutional Arrangements

Institutional frameworks consist of mixes of institutional arrangements, and there are no places with only one type of arrangement in place. Furthermore, due to communication systems there are no places where there are completely isolated systems that do not receive influences from the outside, but there are more open and closed systems. The present configuration of institutions, sectors, organisations and arrangements is the

result of a process in which the interests of the actors and the layers they can influence are worked out to form the configuration. Actors influence the institutional weave, and at the same time the institutions shape the actors. The institutional framework is continuously faced with an evolutionary process that tests the configuration. The process can be stronger or weaker and it can be more of a continuous process or one of sharp and radical changes depending on the flexibility and rigidity of the institutional framework. It is a process of trial and error, where the configurations that fit better with the testing environment survive and are retained, until they do not fit the environment any longer. Different sub-systems are tested in higher-layer processes that sort out which sub-systems will survive, and renewal is generated in the sub-systems (Nooteboom, 2000; Boschma and Frenken, 2006; Hodgson, 2006; Nelson and Winter, 1982).

Different societies have their distinct varieties of habits, rules, norms and varying incentives and punishment systems. There are institutional differences between organisations (in term of routines and business cultures) and territories (in term of legal frameworks, informal rules, policies, values and norms), both between nations and between regions within nations. There are differences between firms in the same region and similar institutions in a firm that acts in different regions, which will affect the outcome of their activities (Saxenian, 1994, Putnam et al., 1993). At the same time there is interplay between actors, organisations and territorial frameworks that sets limits to what kind of activities can be carried out and the possibilities for influencing the framework. It has been argued that clusters grow because they provide an institutional framework that reduces transaction costs and enables innovation processes, and thus are preferable for firms from a localisation point of view (Malmberg and Maskell, 2006).

Institutional frameworks are path dependent and cannot be altered without connection to the established practices. With increased global influences, it has become popular to identify best practices from other countries and organisations, where some parts of a phenomenon are identified as desirable. However, only parts of the social structure are identified and then when it is implemented in another social context in a top-down fashion there are challenges. Laws and regulations are often based on theoretical foundations and an abstracted theoretical knowledge base and need interaction with practical knowledge to work, to interpret and localise practices and make the new institutions operable; for example, it has been a practice among French

labour unions that, instead of refusing to follow regulations they disapprove of, follow them in every detail, which stops production completely or makes it extremely slow (Scott 1998).

Innovation creates social change, either through new ways of organising activities or because new technology creates pressures for new organisational needs. The institutional framework can prevent or facilitate this, and be under pressure to change from different interest groups. Changes threaten the existing order and will conflict with groups and interests of the existing order. Groups that have achieved incumbent positions will always try to defend their positions and defend their interests and solutions (Mokyr, 1992). Actors are also constrained by their past, so-called path dependency, by existing knowledge, habits, rule and norms that influence their actions.

However, the scope for individuals and organisations to carry out activities is important for understanding the possibilities for change of institutions of an economy and innovation. At the same time, societal inertia is a basic feature of institutions, and this provides the basic stability necessary for change (Johnson, 1992; Lanzara, 1998). The more flexible the norms and rules, the greater the possibilities for new inventions; at the same time there is a need for stability among institutions to enable a capacity to carry out innovations, as innovation involves both the generation of new ideas and the diffusion of these new ideas. In both these processes there is a need for alignment of cognitive frameworks, and for this there is a need for shared institutions for communication. Furthermore, it is easier to carry out innovation if there are stable institutions in place, such as financial systems and legal systems. Innovation implies change, but at the same time there is a need for commitment to keep the change stable and for other actors to commit to carrying out and following the change (North, 2005).

The degree of inertia of rules will affect the outcome of innovation in an economy and an organisation. More inertia will make it easier to collaborate to an extent and is conducive to incremental innovations; more flexibility will allow for more radical innovations, but there will be more costs involved in aligning cognitive frameworks (Nooteboom, 2000). It has been argued that clusters are locations where there will be less radical innovations as there is a higher prevalence of established practices that will lock actors in certain behaviours (Nooteboom, 2006)

Over time different institutional arrangements dominate the economy and the way in which other arrangements take place. Depending on which arrangements dominate, different types of innovation can be expected. Societies will likely excel in different types of innovations and also succeed in different markets globally due to these national differences (Hall and Soskice, 2001; Whitley, 2007 and Amable, 2000). Countries have bundles of institutions that fit better together and produce different types of innovations. Anglo-Saxon countries with traditions of liberal free markets are more likely to produce more radical innovations, as their economies are more open to radical changes and are more flexible. Furthermore, their labour forces do not emphasise the same type of capability build-up that benefits process innovations, as there are fewer long-term market relationships. The labour force is also more prone to have a broader competence profile in order to be more employable in more locations (Hall and Soskice, 2001). In contrast, in countries like Germany and Japan, venture capital markets are not highly developed and financing tends to be based more on long-term bank loans than on the equity markets, and the relationships of firms tend to be relatively stable. The arrangements seem to contribute to incremental innovation, and more towards process innovations, as the relations between firms and financial institutes and with labour market organisations are more long-term (Hall and Soskice, 2001; Amable, 2000). Multinational companies enter new locations and bring with them new institutional practices that are diffused to the surrounding location. However their organisational practices need to be adapted in some ways to the local. Therefore it is not likely that all countries will converge into the same configuration, despite strong influences from globalisation.

Despite the fact that there is dominance of some arrangements, monoculture of arrangements is negative for a society. In a society with pure spot markets, with only trade in well-defined products or where transactions are coordinated only by the state, the framework would be too rigid and leave little space for exploring and managing the new uncertainties arising, as these would not have the means for looser collaboration where actors set out to engage in interaction in order to explore more radically (Hollingsworth, 2000). In these cases it is more likely that the societies would generate incremental or process innovations, where production is carried out more efficiently. Similarly if there were only market arrangements in place, there is a danger that there would be an under-investment in basic science (Arrow,

1962), as there are not enough short-term profits from investing in this type of research compared to the total social gains from investment in basic science, and actors will have too short-term perspectives. Likewise, it can be hard for purely market-based actors to break lock-in and path dependency (Grabher, 1993). There is also a danger that groups with poor incomes can have a hard time channelling their needs and that there will be few innovations addressing the needs of these groups, such as malaria in Africa.

However, if state arrangements are too dominant there will be problems with incentives for development of new technology and weeding out of poor ideas, as well as identification and channelling of needs. There is also a danger that processes will be too controlled by managers with inappropriate knowledge and perceptions of reality.

The dominating institutional arrangements can evolve over time; for example, clusters in Mexico that were oriented towards processing products for external actors in strict quasi hierarchy relations have changed over time and horizontal local networks have evolved with more local market and networks relations being used (Markusen, 1996; Gereffi et al., 2002). There have also been implementations of state and network arrangements with investment in complementary research and education facilities.

The strong role of the state in the Soviet Union and its market restrictions is something that could explain the slow growth of planned economies (North, 2005). Having diversity in the set-up of institutional arrangements is a way of reducing risk and complexity, as well as a means to enable different potentially positive externalities. Societies with little diversity in their co-ordination mechanisms have fewer capabilities in adapting to new circumstances (Hollingsworth, 2000). The acceptance of a multitude of ongoing processes is important for growth and resilience to risky environments. The variety in institutional arrangements creates incoherence in governance, but provides capabilities for adaptation (North, 2005).

However, to stay long-term competitive, there is a need for a society to manage long-term continuous change. As everything changes and eventually disappears (Ormerod, 2005), there is a need to be able to adapt to new circumstances. It seems as if it is optimal for a society that desires to have long-term competitiveness and continuous development of innovations to allow for many different types of arrangements and a combination of them, especially in areas and industries involving great uncertainties and much new

knowledge development. Monoculture, or one type of arrangement, is not beneficial for innovations; there is a need for a mix of knowledge bases, such as scientific and engineering knowledge as well as more practical and hands-on tacit knowledge (Scott, 1998). These different knowledge bases are developed differently under different arrangements, and the interplay will also vary. All components are important in the development of innovation, and it seems that a mix of arrangements is positive for innovation.

The chains of relations in place for innovation are complex. Similarly to the way in which networks arrangements can be ideal to manage uncertainty, clusters and cluster initiatives can be seen as places and processes that incorporate a number of institutional arrangements and make them more supportive of innovation and making the interests of private and public actors meet (Helmsing, 2001). Cluster initiatives are close to the actors that hold the relevant knowledge and understanding of what needs to be addressed and how, and can make these interests meet with actors who have resources and means to alter institutions and find financing. Individual companies can independently influence cluster development to different degrees, but the importance of externalities and public goods means that informal and formal networks are often necessary and appropriate for addressing these issues. Broad-based networks can have greater influence than individual members, with more attention, resources and influence.

The externalities that have been theoretically attributed to clusters will not occur in all settings; this depends on the institutional framework. For example, it may not be possible in all countries to develop collaborative associations between firms, research institutes and the public sector to jointly enhance the interest of a cluster, if there are strong antitrust laws, as in Japan until 1961 and in the US until 1984. So even though there was social capital conducive to collaboration in the region, the scope for joint action was limited (Tidd et al., 1997, 2005). In parts of the cluster literature it is commonly argued that it is social capital that facilitates local exchange. However, in satellite districts, as described by Markusen (1996), direct local relations are absent and direct external relations are more important. Similarly, it is often argued in cases on clusters in former planned economies that they lack social capital, as there has been a radical reorientation of the institutional set-up (Coenen, 2004). It is likely that there is always a seed of social capital locally, but its strength may vary greatly. It may be similar with the different cluster externalities; they can be present but more strongly or

weakly, and there are some local features that define the character of a cluster, such as legislation, special science and technology facilities or the existence of special labour market characteristics. Clearly the mix of institutional arrangements and the interplay between them will affect the ways in which clusters can be conducive to innovation.

2.5 Analytical Framework

In order to address the objectives of the thesis, theories regarding innovation, cluster externalities and institutional arrangements are presented. These have served as sensitising concepts, which have given guidance on how to address and analyse the empirical material rather than a theoretical proposition that is tested (Turner, 1991). The main categories explored are the four institutional arrangements – market, network, quasi hierarchies and state arrangements – and the five cluster externalities – intense competition, knowledge spill-over, specialisation, user-producer learning and joint action – which are joined together in the analytical matrix, see Table 5. For innovation performance the two categories of product and process innovations are mainly used.

The data on institutional arrangements and cluster externalities are presented along the lines of the matrix for each case in sections 4.8–4.10. Data on the presence of the institutional arrangements and the cluster externalities is sorted in separate subsections, with discussions of how the institutional arrangements have affected cluster externalities and impact on innovation. Each section ends with a discussion of the case and a summary of the main findings structured in matrices that are compared in chapter 5.

Table 5: Matrix for subsequent analysis

	Intense competition	Knowledge spill-over	Specialisation	User-producer learning	Joint action
Market					
Network					
Quasi hierarchy					
State					

3. Methodology

3.1 Ontology

As scientific debate is often on the level of methodological premises, concerning broad topics such as methodological individualism vs. collectivism or actor rationality vs. path dependency, I will begin by presenting the ontological point of departure of this thesis, which is the basis for the kind of knowledge that we can expect to generate and the methods (tools and techniques) that will be chosen in order to achieve this.

This thesis draws mainly upon sources from innovation studies and heterodox economics, such as institutional and evolutionary economics. In standard neo-classical theory the point of departure is one of methodological individualism and rational actor theories. In the heterodox schools, methodological collectivist ontological views are quite common, emphasising that the individual has little free will, but activities and desires are more the outcome of social structures, rather than agency and the actor's own will. Furthermore, the actor and agency are governed by social structures; the rationality is bounded by the cognitive frameworks that actors receive from the social structures (Boschma and Frenken, 2006; Hodgson 2001, 2006). The social structures are the outcome of previous actions and negotiations of actor and actor groups that shape the social fabric. Also related to this is the fact that there are many scholars who can be described as methodological nationalists or regionalists, who can over-reduce and oversimplify the process and institutional fabric of regions and attribute all the action to specific institutions. These best practice cases are then used as examples or possible remedies for other regions or nations, without regard for the specific context or the real complexity of a multitude of actors and parallel processes in the place where the proponent wants to deploy them (Amin, 1999).

I prefer an intermediate approach, methodological interactionism, that actors are influenced by the structures, but still have their own agency (Hodgson, 2007). This is evident from my viewpoint in the fact that there are commonly changes in social structures, which requires that there is individual agency with incentives to alter structures. Likewise, if there were

no individual agency, it would be hard to understand or explain how the individual appropriates the social structures. Hodgson (2007, p. 13) argues that there is a need for a *“framework within which the transformation of both individuals and structures can be explained. This approach must involve explanations of possible causal interaction and reconstitution, from both individual to structure and from structure to individual. This would mean an explanation of the evolution of individual purposes and beliefs, as well as an explanation of the evolution of structures.”* For this purpose Hodgson emphasises the process of habituation and habits and how they relate to the construction of rules. Following from this, I would argue that actors have bounded rationality that senses are not open to all possibilities. Individuals are affected by previously existing structures that colour perceptions of reality and influence incentives.

There is an objective reality out there that can be studied and understood, and there are mechanisms that exist in human societies that we can uncover. However, our understanding is shaped by the social structures surrounding us, and our own rationally, understanding and desires are affected by the social structures. A number of informal institutions tend to be similar in different countries, the same type of institutions exist, but the design varies (North, 2005). This suggests that there are some mechanisms and phenomena in human societies that are universals, that is, certain practices and behaviour are common throughout all human societies. Examples of this include: division of labour, classification of space, institutions (organised co-activities), leaders and laws, myths and narratives, self distinguished from other, trade, etc. (Brown, 1991). As social science researchers we can often influence process in the objects we study, the humans that we interact with and the responses that we get, which can disturb our results. However, over time we can come closer to understanding how the world works.

This line of thinking is close to the school of critical realism, which has influenced my thinking while working with this thesis. The critical realist approach is that there is an independent reality, but we can only partly observe it, and that our observations are not the same as the reality (as claimed by empiricists). I would not say that I have fully employed a critical realist approach in designing the study and when carrying it out, but it has guided my work practices, how I select sources and triangulate them to find countervailing points of view. Critical realists can use most methods in their work to uncover the reality; the difference lies in the awareness of one's own

presumptions and that iterative processes are beneficial to refine these findings. With this approach there is a danger of essentialism, i.e. ascribing collective characteristics to groups and phenomena that do not reflect reality, as the Nazis did with Jewish people. Moderate essentialism is hard to avoid, and probably this also reflects how brains build cognitive frameworks (Frith, 2007). However, radical anti-essentialism will lead to the same thing as essentialism, just as extreme relativism leads to the absence of claims to truth. Another challenge with critical realism is that there is a tendency to overemphasise the influence of mechanisms and social structures and lean more towards the end of methodological collectivism. I agree with methodological interactionism (Hodgson, 2006) that there is individual agency and this is crucial for understanding how social structures are changed and how socialisation processes take place.

3.2. Methodological Choices

The aim of this thesis has been to explore how institutional arrangements affect cluster externalities and what the impact is on innovation, and to analyse the innovation outcome in the clusters with the help of the analytical framework, in order to find out whether this can be attributed to cluster externalities and the impact of the institutional arrangements.

To address the research question, a comparative case study method was chosen. The thesis is of an exploratory nature, and as Yin (1994) has argued, case studies are appropriate when a researcher wants to address complex social phenomena with an ambition to provide insights to build a theory rather than to test it; when the researcher is posing “how” and “why” questions to a body of material in which the researcher has little control over the events and which is a contemporary phenomenon in a real life context, which matches the objective and concepts that is studied in this thesis.

Furthermore, in this thesis no theoretical proposition has been set up to be tested, but the approach has been to explore the empirical data to find hypotheses about how institutional arrangements affect cluster externalities that have an impact on innovation and to explore the possibilities for this to explain innovation performance in the cases. The theories presented in the theoretical chapter of this thesis are sensitising concepts, which are used to identify elements that should be studied further, and in a similar way the

analytical framework is a sensitising scheme that gives guidance to address and analyse the material rather than a theoretical proposition that is tested (Turner, 1991). In order to find out relations there is a need for some flexibility in the schemes, as we interpret the data with the aid of theoretical concepts, but the ambition is also to find relations that are beyond the existing theoretical relations. At the outset of the project there was no fixed hypothesis set, and the research scope has rather narrowed down in iterative steps in the course of the project. The process in this thesis has been one of gathering data and matching this to the categories, but there have also been alterations of categories after the findings in the data.

As the project is an explorative research process, I have considered it important to have a method where I can use different types of data, both quantitative and qualitative, to gain different types of insights. The comparative case study method has allowed me to work flexibly and to use multiple data sources. By comparing cases, more generalised and robust findings can also be generated (Eisenhardt and Graebner, 2007). The result of a comparative case study comes from analytical rather than statistical generalisations (Yin, 1994) and here the cases are not sampled units, but have been chosen due to their richness in information and as multiple analyses to provide comparable insights.

Furthermore, Yin (1993) stresses that a comparative case study is an appropriate approach to explore a particular phenomenon, as well as the context, either because the context contains important explanatory information about the phenomenon or the boundaries between the phenomenon and the case are not clear, which is in line with my objectives to explore both the role of institutional arrangements for clusters and innovation, and the importance of institutional arrangements and clusters for innovation in my cases. In addition, it is hard to completely separate the institutional arrangements and the clusters from their contexts.

3.3 Research Strategies and Research Design

3.3.1 Selection of Cases and Units of Analysis

The methodological approach has been an exploratory comparative case study. This is primarily an inductive approach, where there is a need for material that is rich in information, rather than an application of statistical

data to find the cases that are the most representative. *“The logic and power of purposeful sampling derive from the emphasis on in-depth understanding. This leads to selecting information-rich cases for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the purpose of purposeful sampling”* (Patton, 2002).

The cases chosen were the outcome of path dependency and purposeful sampling. The empirical context came out of a personal interest in the region and prior research projects, which made me interested in exploring the role of clusters for innovation in the agro-industries of Latin America. The investigations began with a literature review and interaction with local academics and carrying out some initial field trips. However, the purpose of the thesis and the empirical scope was narrowed down in the process, to the sugar industries of Brazil and Cuba, as these were cases where there was clustering and where innovation had taken place. When exploring the cases one obvious factor that differed was the set-up of institutional arrangements. Cuba is a planned economy and Brazil a market economy, but there have also been alterations of the institutional arrangements over time that would allow analysis of how the differences in institutional arrangements affect cluster externalities that have an effect on innovation. I decided to focus on three cases: sugar clusters in São Paulo and the North East (Pernambuco and Alagoas) region of Brazil, and in Cuba.

I had identified sugar clusters in all the cases; e.g. in Brazil, approximately 80% of the sugarcane is harvested in the Centre South of the country, and the other 20% is produced in the North East. Furthermore, in the state of São Paulo and the city of Piracicaba a cluster initiative called APLA that includes a wide variety of actors was initiated in 2006 to support the local cluster.

There are distinct differences in the institutional arrangements of the three cases. Brazil is market-oriented, but with quite distinct changes in the institutional arrangements over time that have also affected institutional arrangements in the sugar industry. There are also distinct differences in economic development and innovativeness between the two regions. São Paulo is the most advanced region in the country and the North East the least developed. Cuba, being a planned economy, has a radically different set-up of institutional arrangements in place, which also to some degree have

been altered over time. This can be characterised by periods of centralisation (more state-controlled) and decentralisation of institutional arrangements (with some more market, arrangements) (Brundenius, 2002). The state is dominant in all institutional sectors, but there are some elements of markets, networks and quasi hierarchies. A comparison of these cases will provide feedback to the role of different institutional set-ups in order for certain cluster dynamics to occur and affect innovation.

Furthermore, in the sugar and ethanol industries there has been upgrading/innovation. This is a broad and complex industry with both low- and high-tech features, connecting both rural and urban actors, consisting of a web of a number of economic activities, such as sugarcane production, sugar production, ethanol, alcohol, electricity production, and other by-products such as paper board, yeast, and animal feed. There has been innovation in many different forms in all of these cases.

In addition, the industries are very important in both countries. Until the 1990s Cuba was the largest sugar exporter in the world, and Brazil number five; the situation today is the reverse (Pollitt 2004). To explore why this has happened and whether there was any connection to clusters and innovation is an interesting challenge.

By comparing the Brazilian and Cuban cases, answers are expected to be generated to questions about whether different types of institutional arrangements support different types of externalities that support the innovation in clusters, and have different innovation outcomes.

The cluster is a meso-level concept which has a territorially delimited scope of inter-organisational and inter-actor relations. The focus of this thesis is on the systemic level of the cluster, rather than on specific individuals or firms. It explores how different ways of organising relations through different institutional arrangements affect how cluster externalities have an impact on innovation. The externalities and arrangements can be interpreted as mechanisms and structures which are limitedly observable, with the outcomes of innovations that are observable only to some extent. The actors and firms in the cluster can be observed, but how we make the delimitations and how we interpret who belongs to the cluster is clearly decided by theoretical considerations.

A common critique of the concept of clusters is that it is vague when it comes to delimitations; I have however followed the lines of the proponents of cluster theory who suggest that it can be seen as a heuristic tool that guides processes of fitting data to find delimitations and to identify relevant actors and processes concerning where dynamics will occur (Porter, 1998).

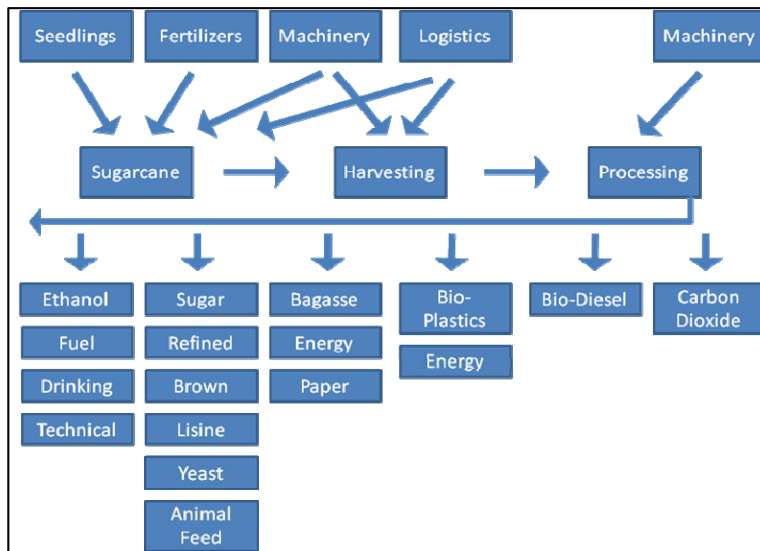
As this is an explorative study, I have used a heuristic multi-level approach to clusters, including large and small geographic areas as well as varying numbers of economic activities. For example, one could argue that Cuba can be seen as a cluster in itself, but it could also be argued that one province of Cuba is a cluster or that the region around a sugar refinery is a cluster. Similarly in the case of Brazil, the regions of the State of São Paulo and the North East can be seen as clusters, but these can also contain clusters in sub-regions, as in the case of Piracicaba which is a micro region of São Paulo, or the economic system around a large sugar refinery could be a cluster. The analysis has been carried out for these different levels in order to identify important relationships.

Another challenge in delimiting clusters relates to the set-up of relations in clusters, as in some narrower definitions Cuba would not be considered a cluster at all. Cuba is a planned economy and is different in its institutional set-up and the terminologies used for describing its economy. The low degree of competition and networking would bar Cuba from having clusters. In a broader definition of clusters, by contrast, with only limitations to the concentration of economically related actors in a geographically delimited area, there is a cluster in Cuba. I would also argue that Cuba's difference is what makes it particularly interesting. It makes it a good case for exploring the role of institutional arrangements for cluster externalities. The Cuban process, despite its difference in vocabulary, can be interpreted through my analytical framework. Furthermore, there are scholars and policymakers who argue that there are clusters in Cuba, e.g. descriptions of the biotech cluster of Western Havana (Thorsteinsdóttir et al., 2004; Núñez Jover et al., 2008), and that pursuing cluster-based strategies is a viable and desirable option for Cuban policymakers (Garcia, 2005; Miller et al., 2007).

There is not only a challenge concerning the geographical scope, but also with regard to the kind of economic activities and actors to include in these processes, as the cluster is not the same thing as an industry. The strongest driver of developments related to sugar in recent years is related to ethanol,

and a great deal of the data gathered concern sugar activities related to ethanol. In our analysis of the sugar cluster the economic activities included go beyond the traditional delimitation of the sugar industry and the standard industrial classification systems. At the centre of the value network that is the point of departure for this thesis is sugar and ethanol production from sugarcane, see Figure 2. This view of the sugar value network has guided me in choosing which types of respondents to interact with, but also which kind of data on outputs from clusters, as well as the understanding of what the clusters are and their institutional set-up.

Figure 2: Sugar value network



3.3.2 Selection of Institutional Arrangements for the Case Analyses

Institutional arrangements are social constructions that connect people's behaviour to rewards and punishments in the form of other's actions, which can provide incentives and enable or constrain innovation. As with clusters, the demarcation lines are not always clear cut, and there can be a wide range of classifications. In this thesis I decided to keep the variables as few as possible in order to reduce complexity, but at the same not too few so that

explanatory power was lost. Due to both my own empirical data and a large empirical survey of clusters (Enright, 2000) I choose to start with four types of institutional arrangements that seemed to be of the highest relevance for the cases: market, network, quasi hierarchy and state arrangements.

The point of departure for creating the categories of institutional arrangements was Hollingsworth's (2000) framework for institutional analysis of innovation. Of his categories, hierarchy was removed as this is a study of inter-organisational transactions; the categories of networks, associations and communities were merged, as they are similar enough to merge into one category. In addition, the category of quasi hierarchy was added, as an arrangement whose importance was indicated by my empirical material as well as by findings in the literature review (Markusen, 1996; De Langen, 2004; Gereffi, 1994).

3.3.3 Selection of Externalities for Case Analyses

We are interested in the mechanisms of clusters that have an impact on innovation. In cluster theory there are discussions of static and dynamic externalities, i.e. externalities that reduce transaction costs and increase efficiency and externalities that support innovation by providing incentives or mechanisms for enabling innovation. There are also negative externalities that create costs or prevent innovation.

For operational purposes I have also tried to restrict the number of categories of cluster externalities, to the ones most frequently connected to innovation in the literature and also to merge related mechanisms. For the same reason I have also abstained from particular categories of negative externalities, such as lock-in, vested interests, path dependency and congestion. I have merged these themes in the larger categories that discuss both negative and positive outcomes of the externalities for innovation. How these externalities can have an impact on innovation as described in the literature is summarised in Table 1. The outcome of the mergers of groupings are five categories: i) intense competition, ii) knowledge spill-over, iii) specialisation, iv) user-producer learning and v) joint action.

3.3.4 Innovation

In this study I have used OECD's (2005) definition of innovation: "*An innovation is the implementation of a new or significantly improved product*

(good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.”

These innovations can be new to an organisation, new to the market or new to the world. In this study, to restrict the number of categories for analysis, two main categories in which all other types of innovation can be grouped will be used: product innovation and process innovation.

I also use the categories of incremental and radical innovations. Radical innovations create fundamental changes in an industry; they reduce the value of prior knowledge and create uncertainties within existing organisations. An incremental innovation is a minor change that strengthens prior knowledge within an organisation.

3.4 Operationalisation

The aim of this thesis is to explore how institutional arrangements influence cluster externalities and the impact on innovation. The independent variable of the analysis is the category of institutional arrangements and the dependent variables are cluster externalities and innovation.

The way to operationalise the study has been to first identify and describe the institutional set-up of the clusters and provide a historical introduction to the growth of the sugar clusters of the cases, with a particular focus on the time from the 1970s onwards. This description is the basic material for the context of the study and is a way to anchor changes that have taken place over time in the institutional set-up. This is also needed for the discussion of the degree to which innovation is related to cluster externalities.

This is followed by a presentation of the innovation outcome in the cases. In order to create a rich understanding there is both qualitative data, e.g. interviews, news articles and academic literature, as well as quantitative data, e.g. innovation surveys, patents, scientific articles, and data on productivity and production. These data are then used to discuss the innovation outcome and innovativeness of the different clusters.

In the next section my data for the different cases are presented according to the matrix of my analytical framework, see Table 5. The framework has been my sensitising structure to address the material, and when analysing the empirical material I have looked for indications of how the institutional

arrangements have affected the externalities in the clusters. I have searched for the presence of the institutional arrangements and the cluster externalities, and whether there have been arguments for how this may have affected innovation. The indicative data come from the same type of sources as for the innovation outcome, but lean more towards the qualitative than the quantitative sources, as the data cover more complex relations. Each case contains a presentation of the indications for how the institutional arrangements have influenced the cluster externalities along the structure of the matrix, but is also contains a summary where the main findings of each case are presented and with discussions of changes over time, to see whether there are differences in how the institutional arrangements affect the cluster externalities and to detect relations to the innovation outcomes of the particular case.

In the comparative analysis the main findings of the case analysis are compared. There is a comparison of the role of cluster externalities for innovation in the different clusters, a comparison of how institutional arrangements have influenced the cluster externalities in the different cases, the interaction of different institutional arrangements and externalities, and dedicated sections on some important observations of particular interest regarding market, network, quasi hierarchy and state arrangements that have had an searched impact on cluster externalities.

3.5 Data Collection and Analysis

The case study is a comprehensive approach and research strategy (Yin, 1994, p. 8) and is not to be equated with qualitative research, but can be based on qualitative and quantitative material. Furthermore, there is a wide range of choice of techniques for data collection and analysis. Eisenhardt (1989) has also stated that for exploratory studies multiple data collection methods provide a stronger validation for building theories. The data collected for this thesis come from both qualitative and quantitatively oriented sources, and from primary and secondary sources such as interviews, surveys, observations, newspaper articles, books, brochures, scientific articles and policy documents, as well as quantitative data such as statistics on patents, innovation surveys, scientific articles and productivity measures of sugar and sugarcane output.

The material for these case studies was gathered on six field trips, carried out between 2006 and 2008, three of them to Brazil and three to Cuba. During these field trips contacts with policy makers, firm representatives and researchers have been established, with single and repeated visits. The respondents have also been contacted afterwards through email correspondence. Furthermore, data have been gathered throughout the period from library resources, scientific journals, newspapers, Internet sites, national statistical agencies, patent and scientific article databases.

3.5.1 Primary Data

The most important tool for gathering data of this sort has been interviews, through which one can get more in-depth understanding of some of these aspects. This does not give direct access to reality, but it may be the only tool. I have used what Denzin (1988) would call super-informants, people who are more knowledgeable than others in a group about the issues at hand. I have tried to get in contact with representatives with as central positions as possible in relevant organisations, in the hope that these will have broad view not only of their organisation, but also of issues in the cluster. However, these people can sometimes be hard to get in contact with and need time to respond. This has been a great challenge, as I have had limited times in the locations, being external to them and travelling from a great distance. In this work it has been a great help to have local counterparts who have assisted with booking meetings and planning agendas, and also in identifying who are the key actors to interact with. The counterparts have also given legitimacy that has opened up the doors to enable the meetings.

The respondents have been found through the local counterparts, but also through the Internet and literature reviews. What is important to keep in mind, though, is that these actors often are not neutral actors, but have their own ideas that they want to transmit and diffuse. In order to overcome the bias of the data from the actors, the ambition has been to triangulate the responses by incorporating the opinions of different stakeholders. Interviews have been carried out with a wide array of actors, such as firm leaders, interest organisations, union activists, researchers and policymakers, from

national, regional and local levels.⁶ Due to the time constraints, a limited range of actors have responded, and one can always wish for more respondents. Table 6 presents the number of respondents in each category.

Table 6: Distribution of respondents

	Firms	Research Organisations	Policymakers	Associations & Interest groups	Total
São Paulo	2	6	15	4	26
North East	2	2	10	4	18
Cuba	4	8	2	0	14

It is notable that the case with the largest number of respondents is from São Paulo. The reason is most likely that it was easier to get access to interviewees in Brazil, and two trips were made to São Paulo and only one to the North East. However, one category that is low in representation is firms. It was very hard to get access to respondents; many of the desired respondents would not agree to an interview with us, especially those in São Paulo. This may be due to visitor fatigue, as Piracicaba in the last few years has received many national and international visitors interested in biofuel development in Brazil.⁷

In Cuba, after consultations with local counterparts, it was deemed less relevant to engage with local trade unions. The trade union CTC (The Central Organization of Cuban Workers) is closely linked to the governing party PCC (the Communist Party of Cuba and our local sources indicated that the views of the union were likely to coincide with the official views. There are also fewer respondents from Cuba, which is because it is harder to get access to respondents from industry or ministries. The partial lack of respondents in Cuba in total and from local actors and interest groups, and the lack of firm respondents in the Brazilian cases, has been compensated by data from other types of sources.

⁶ For a complete listing see the list of Interviews at the end.

⁷ The cluster organisation APLA was partly created to take care of foreign visitors that arrive due to the global interest in ethanol as automotive fuel.

The interviews have been of a semi-structured character guided by the ideas of clusters and innovation, in the form of a list of questions to ask prior to the interview. The interviews often evolved into discussions, and some took place over longer periods as we had the time to make field trips together with respondents, during which there were possibilities to talk with the respondents more informally. Typical questions asked were:

- Who are the key actors?
- Successful strategies, of collaborative nature?
- What is their opinion of cluster initiatives?
- How are relations governed?
- What is their role in the cluster?
- Which policies and activities have been undertaken and which have been more successful?
- What kinds of innovations and upgrading have been taking place?
- Can this relate to clustering, cluster activities and policies?
- How do the cluster policies link to the greater innovation policy framework?

The interviews were not recorded. Many of the interview locations were places where it was not possible to record, such as in refineries, plantations and labs. I was also on more than a few occasions travelling with the respondents where discussions/interviews were taking place over long periods of time. When there have been doubts about data from respondents, to corroborate findings I have interacted through email with a number of the respondents after returning home, as well as with local counterparts.

3.5.2 Secondary Data

The primary data are supplemented with secondary sources, such as more qualitatively oriented data from newspaper articles, books, Internet sites, brochures, conference presentations, presentational material from the organisations visited, scientific articles and policy documents, as well as more quantitative data such as statistics from innovation surveys, patents, scientific articles, productivity measures of sugar and sugarcane output. The sources for this data are original from national statistical agencies, as well as

from publications from ministries and interest groups. The data are related to the three different cases.

The innovation surveys come from the Brazilian Institute of Geography and Statistics (IBGE), which has carried out four surveys of innovation in the Brazilian economy called Pintec, (in 1998–2000; 2001–2003; 2003–2005; and 2006–2008). These are based on the third edition of the OECD Oslo manual of innovation indicators and are compatible with international surveys such as the EU Community Innovation Survey (CIS).⁸ For this thesis there are interesting data on innovation in the ethanol and coke industries and the metal-mechanical industries that will be used as indications for the mills and the suppliers of process equipment. The data for these categories were not separated for the regions, and the data for the regions are only provided in totality for all firms of the regions. Still these are useful data for the discussions and have therefore been included in the cases. The Cuban National Statistics Office (ONE) has also gathered data on innovation and rationalisations, but it is not based on a method comparable to the Brazilian data, and includes only a limited set of variables.

I have also carried out an analysis of patents in the cases. Patents in themselves are not innovations, but inventions. They are however among the limited internationally comparable data that can be related to innovation, and here they are used as an indication of innovation outcome. When exploring the patents a number of search strings were used. The search covered was WIPO, US-approved patents and EU patent data from the Freepatent's database. To make the data relevant to the clusters there was a search for patents separated for the three cases, by looking for country of origin for patent holders. When searching for data from Cuba, no additional search string was needed. In the search for data from Brazil there was an additional search for inventor city, indicating the geographic location of the patent holder so that the holder could be connected to either the North East or São Paulo. To create these search strings broader search categories were created. This was done by searching the Brazilian patents in

⁸ The Community Innovation Surveys (CIS) are surveys undertaken by national statistical offices from the EU, Norway and Iceland. These surveys are harmonised, to provide comparable information on the innovativeness of different industries and regions. The data are used for the annual European Innovation Scoreboard.

order to find cities in the North East and São Paulo where patents had been filed, and adding them to the search string.⁹ It is likely that there are a few more patents from São Paulo than the ones I found, since there are probably more patents from that state that were not captured by this search string, as inventors may only have stated the place as Brazil and not São Paulo, or a minor city in the State that was not included in the search string. There are also challenges with misspelling of city names; I found one patent where Piracicaba was spelt Piracocaba. However, instead of manipulating all patents, which can create biases, the decision was made to stay with what was found in search strings but make multiple searches.

All patents have been included, so if a patent has been applied for in more than one country it can be counted more than one time. WIPO does not have patents in the early period of our search, and neither US nor EU patent databases contain all the patents filed. Therefore the search has been done for all three bases. At the same time, allow the same patent to appear more than once can be considered as an indication of how important the patent is.

The point of departure was a search for patents filed in the main sugar category of the international classification system called class C13.¹ This, however, did not capture all patents relevant in the cluster; for example, it was missing patents relevant to ethanol diversification. After this the search was opened up for patents that had sugar in the abstract, to allow for more diversification and innovation to be observed. When exploring the categories in which these patents are filed, one can see a broad development. To make the search even broader, the search string was widened to look for all patents with sugar in the text. There are numerous other categories, such as medicine, with patents for vaccines using sugar and derivatives from sugarcane in the case of Cuba, but also machinery, foodstuffs, chemical processing methods, ethanol production, production of plastics, cellulose pulp, cement,

⁹ For São Paulo the search string became: Paulo or Salto or Piracicaba or lorena or Sertãozinho or Botucatu or SP or Campinas or Americana or Sertãozinho or Pirassununga or Cotia or Araraquara or Vinhedo or Guarulho or Santos or (Ribeirão Preto) or (Caetano Do Sul) or (Serra Negra) or (Santana De Parnaíba) or (Santana do Parnaíba) or (Bosque da Saúde) or (Vila Susana) or (São Bernardo do Campo).

For the North East the string was: Pernambuco or PE or Alagoas or Maceio or Recife or AL or Coruripe or Petrolina or Olinda or (São Miguel dos Campos) or (Coroa do Avião) or (Jaboatão dos Guararapes).

explosives. The problem with making the search string broader is that clearly irrelevant patents are also included, such as a patent for a Colibri bird feeder. To further explore the patents to acquire a better picture and also capture patents related to the ethanol industry, there was a search for Ethanol and Alcohol in the abstract of the patent and anywhere in the text. However, there are complications with this, as patents with sugar and ethanol/alcohol in them capture other types of patents that relate more widely to chemical processes than to the sugar industry based on processes and products related to sugarcane. The best match was with the search made for Sugar Cane and Sugarcane anywhere in the text, which was also representative in relation to the proportions of patents in the different cases and the development over time. This became the category that was used for the other patent analyses.

When searching the Cuban patents, I had an initial worry that Cuba would not be interested in patenting for ideological reasons and thus make it hard to use patents as a source for comparison. This seems not to be the case, however, as there are patents from as early as the patent register started keeping track, and it is also at a pace that seems to be increasing (Tamayo, 2009). Furthermore, Cubans seem to acknowledge the importance of the biotech sector and the potential and importance of protecting their intellectual properties (Grogg, 2009).

In a similar fashion the number of scientific articles published by authors with addresses connected to the different clusters has been gathered. The source for this data is the Web of Science with Conference Proceedings (ISI), which interfaces and makes a meta-search of five other databases: i) Science Citation Index Expanded, ii) Social Sciences Citation Index, iii) Arts & Humanities Citation Index, iv) Conference Proceedings Citation Index-Science, and v) Conference Proceedings Citation Index-Social Science & Humanities. In the search for data from this database, the parameters have been sugarcane only, and then country of origin, but also the address of the origin of the author, for Cuba, Brazil, Piracicaba, (São Paulo or SP and Brazil) and for the North East (Recife or Maceio or PE or Pernambuco or Alagoas or AL and Brazil).

3.5.3 Data Analysis

The analysis of the data was done in iterative steps, as data were gathered continuously during the project, initially with a broader scope, and as the project became more focused the data search became more specific. Initially

the search was for data concerning the institutional set-up of the cluster and also evidence of innovation. The approach initially was more explorative and using data that were more qualitatively oriented, with more anecdotal findings of innovations, be they radical, incremental, new offerings, processes, markets or organisational set-ups. The data came from the interviews from the field trips, and also from secondary sources.

Later in the process, when the aim was more specific, began the abstraction process of data according to the categories of the analytical framework. The focus has been on finding data on what institutional arrangements are in place, what kinds of externalities can be observed and what the innovation outcome was, and whether this changed over time.

It has been a challenging process, and it is not always completely straightforward which categories data should be sorted in. There are similarities as regards specialisation and user-producer learning, for example, and also some phenomena can be market-based or network-based, with the risk that some of the abstractions may end up in the wrong categories. To give some context to the processes, each case therefore includes both historic backgrounds and appendixes presenting some of the specific stakeholders that have been interviewed.

With regard to the analysis of the relation between institutional arrangements and cluster externalities, this is summarised in tables at the end of each case in order to enforce strictness in the analysis and also to gather material that is more easily compared in the comparative analysis of the data. This approach has required me to move beyond initial ideas of relations, and improved my possibilities to find accurate and reliable findings.

Throughout the process I have used both quantitative and qualitative sources, of both primary and secondary data, in order to abstract the data for the analytical categories of institutional arrangements and cluster externalities. To describe the innovation outcome of the cases, I specifically decided to include data from more extensive sources, with the ambition to provide some robustness to the analysis. For this reason tables were created that provided indications of the innovation performance in the different cases over time and enabled comparison of the cases. Tables were created with data on innovation performance in Brazil and Cuba based on the innovation surveys. There are also tables on the number of patents that had been filed in each case and in different categories, for types of patents with

regard to product or process innovation, likewise tables of cited and published scientific articles about sugarcane.

It is commonly argued that for firms and regions to stay long-term competitive it is necessary to be innovative. If organisations are able to implement innovations, long-term productivity should rise, and thus if productivity rises it could imply that the region is innovating without it being reflected in measures such as patents and articles (as in the case of the North East). Therefore tables on productivity measures were included, as indicators on an aggregated level for process innovations and the impact of innovations and institutional arrangements on innovation performance. The measures used have been data on the output of sugar, sugarcane and ethanol, levels of sugarcane, sugar and ethanol yield.

The analysis of the patents and scientific articles also gave inputs for wider searches, with names of relevant firms, organisations and persons to explore in the secondary material. It also provided background information and a source to corroborate findings from the interviews on innovations. It also gave a view of relevant networks, as it indicated that many of the patents were filed by networks or people from industry and research institutes, which in turn gave input to the analysis of the institutional arrangements in place.

3.6 Reliability and Validity

Reliability and validity are essential in order to ensure that the findings of a study are scientific. Reliability means that the results of a study will be repeated if the process is carried out again (de Vaus, 2001). Validity can be separated into several components: internal validity, external validity and construct validity. Internal validity refers to the extent to which one can draw clear conclusions from the research. External validity relates to how far generalisations can be made beyond the specific study. Construct validity refers to how well the theories of cause and effect represent the real-world situations that they are intended to model.

In order to assure internal validity, I have worked with triangulation of sources (Duffy, 1987), i.e. using different respondents from different actor categories with potentially differing interests in order to verify or contradict responses. This triangulation have been combined with data triangulation

with different types of sources, so that interviews have been combined with data from newspaper articles, books, Internet sources, academic articles. Similarly, there is triangulation of intensive data and extensive data. Furthermore, the findings and data have been verified by local counterparts and also from articles and presentations during the process. This has been done not only to verify the findings but also to search for alternative ways of explanation.

In order to achieve external validity, I have chosen to work with three cases and the development over time in the cases. Through this approach we can decrease the number of possible external explanation factors. Locally specific factors, such as local natural conditions that remain the same over time, can be worked around when comparing each case over time and international factors that can influence the cases may be worked around by comparing three different geographic locations.

In order to achieve construct validity, Yin (2004, p. 34) suggests using multiple sources in order to show a chain of evidence. In this study the approach has been to combine the exploration of relations between institutional arrangements and cluster externalities and for individual processes, as well as more quantitative data that illustrating the total innovation outcome in the clusters. This type of approach will indicate correlations and areas to be further explored.

3.7 Limitations and Challenges

The results of exploratory research are usually more of the nature of “why” and “how”, than “how often” or “how many”, and there are intrinsic challenges in generalising this to a large population. The outcome of this research project is more of the nature of generating hypotheses that need to be further corroborated by other studies.

There is a danger that a researcher has a very fixed idea of how things are related and searches for examples to prove the theories, and in this way locks out alternative relations and explanations. The approach of triangulation can counteract this to some extent. Furthermore, the use of local counterparts and colleagues to review the material has been an approach to counteract this. Also, the interviews have been carried out in a semi-structured way, which has allowed for alternative responses to the expected ones.

Brazil and Cuba are developing countries and therefore there are some additional factors to be considered. There are cultural differences that one needs to be aware of. I speak and understand Spanish, but not as well as Swedish or English, and my Portuguese is more limited. The respondents' English has often also been limited, so there are risks of misunderstandings and misinterpretations. On many occasions I carried out the interviews together with my supervisor, which has allowed data to be secured through the presence of two persons. Likewise, the time in the field was limited, and not all actors were willing to respond to my approaches to verify data afterwards. This is something I have tried to overcome by asking other local counterparts to verify findings or obtain data through other sources. The term of cluster was quite widely recognised in the Portuguese setting, as there were a number of policy initiatives to promote cluster networks, whereas in Cuba the term needed more explanation. My approach has been to try to describe my concepts as clearly as possible, bringing with me some books, Powerpoint presentations and graphical illustrations of concepts if needed to clarify my points.

4. Empirics and Analysis

This chapter begins with a historical introduction to Brazil and then a description of the institutional framework that is the same for both the Brazilian cases and then a presentation of each case. This is followed by a historical introduction to the Cuban case and a presentation of the institutional set-up.

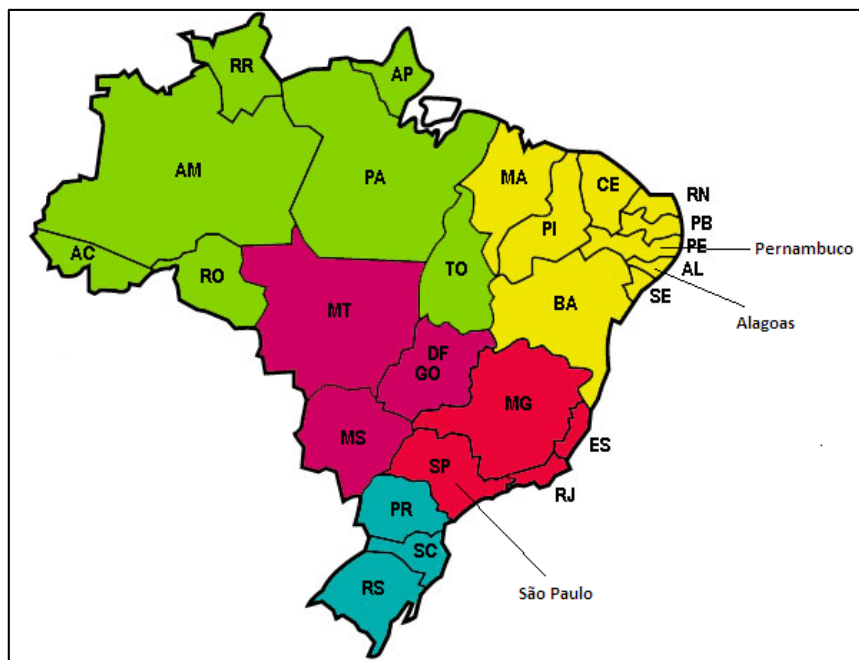
After this comes a section that presents the innovation outcome of the cases, including data from a survey of innovation performance in Brazil and Cuba, patent data, a discussion of innovation types, scientific articles, long-term innovativeness with data on production and productivity. This is followed by a presentation of data on important innovations, gathered from interviews, newspaper articles, books and patent descriptions. The section is summarised with a description and analysis of the innovativeness and innovation outcome of the cases.

After this comes a presentation of the institutional arrangements and cluster externalities for each case and a discussion of how these are related, how they have influenced innovation and development over time.

4.1 Historical Introduction to Brazil

The sugar industry has a long tradition in Brazil, and the first Portuguese colony in the country was established around sugar with the São Vicente mill in 1531 in Pernambuco, the North East of Brazil. The colony was developed around sugar production. The colony began to boom in 1540 and continued to grow for a hundred years; by 1600 there were over 100 *engenhos* in Pernambuco. In 1630 there was a conflict with the Dutch who took over Olinda in Pernambuco and appropriated technology that was transferred to other Dutch colonies in the Caribbean. This broke the Portuguese sugar production monopoly. Also, the British and the Spanish acquired the knowledge and developed colonies in Cuba and Jamaica. This ended the first Brazilian sugar cycle and the industry went into a phase of decline until the end of the 18th century.

Figure 3: Map of Brazil



In 1822 Brazil declared independence from Portugal and the first steps to industrialisation were taken. Prior to independence industrialisation had been prohibited in the colony. Railways were built and some industry was implemented; for example, a steam-powered sugar refinery was built in Santos in 1836. In 1889 the Brazilian Republic was created. There was an increase in the initiation and development of infrastructure projects, such as railway networks, hydro power plants and new ports for exportation.

The North East was the leading sugar region and would remain so until the 1920s, when it was replaced by São Paulo in Brazil. Up to the First World War Brazil had been successful in exporting to the European markets and the economy had grown rapidly. However, after the war, the European and American markets became protectionist and closed to the Brazilians. This was a halt in the economic development of Brazil, but also the starting point in São Paulo for a change of dominant crop from coffee to sugar. This era saw the first experiments with alcohol as a fuel for cars. In 1925 the first experiments were undertaken and in 1927 in Pernambuco the first co-

operative alcohol refinery for the production of ethanol as a car fuel, “alcool-azulina” was set up (da Graça, 2006).

In 1930, Getúlio Vargas staged a coup and introduced what has become known as the Novo Estado. Vargas vision was to industrialise the country and in the process he forced industry to organise itself in interest organisations and made labour do the same. Their interest would then be mediated and taken care of by the government.

In 1933, the Institute for Sugar and Alcohol (IAA, Instituto Açúcar e Alcool) was created. The purpose was to organise markets, by setting production quotas for cane and sugar, to set prices and to control the sugar trade. Ethanol production was a minor activity until the 1970s. The IAA was active until the end of the 1980s in regulating processes and quotas (Martines-Filho, 2006). The IAA act also stipulated that no sugarcane processor could be established without IAA approval (Signorini et al., 2010). São Paulo and Centre South became the most important part of the country, not only industry-wise, but also population-wise. Together with the loss of exportation opportunities, the local markets and in particular the Centre South grew in importance over the North East

The state began to take on a more active role in order to develop the economy by industrialisation. As part of these policies and among the different initiatives to stimulate the sugar industry, laws were implemented that made it mandatory to blend petrol with ethanol. This had been implemented in periods previously a well, such as in 1931 with a 5% mix, and later this percentage was raised to 20%. In 1941 and during the war, a 40% blend was used in the North East Region. In 1941 there were 44 distilleries that produced 20.2 million gallons per year.¹⁰ These activities increased further after the end of the Second World War, when large-scale import substitution programmes were launched. The government created large industrial projects and energy plants hoping for forward and backward linkages that would stimulate the economy. In the 1940s and 1950s the industry was characterised by the extensive growth of cultivated land and some investment in research at the Agricultural Institute of Campinas (Instituto Agrônômico de Campinas, IAC) (Fronzaglia and Martins, 2006).

¹⁰ 1 US gallon is 3.785 litres.

At the end of the 1960s the country experienced sluggish economic growth and fewer resources were provided to IAC for research; there was severe inertia in the sugar economy. The industry was using outdated and unproductive mills and cultivating methods. In order to counteract the challenges in the 1960s there was both government action initiated and private efforts in the form of the Sugarcane Technology Centre (CTC).

The government introduced a number of initiatives among these was a modernisation programme led by the IAA, initiated in 1970 to reduce the number of old and unprofitable mills and to support mergers, acquisitions and relocations of the remaining mills (Fronzaglia and Martins, 2006). They embarked on improving the infrastructure for exporters. They also began R&D and technology diffusion programmes that supported genomics and agriculture practices. One of the most well renowned projects was the creation of the national programme of improvement of sugarcane, Planalsucar (the National Plan for the improvement of Sugarcane, Plano Nacional de Melhoramento da Cana-de-açúcar), in which new cane varieties were created (Ueki, 2007). The programme had its headquarters in Piracicaba (Tosi et al., 2008)

In 1970 Brazil had few sugarcane varieties, with only around 10 varieties used in total. These had been developed by IAC and stations from the ministry of agriculture in Rio de Janeiro and in Pernambuco (Peixoto, 2008). After the efforts of Planalsucar, CTC and the São Paulo state government's institutes IAC and Instituto Biológico (IB), a broad variety has been developed. IAC had begun research on sugarcane in the 1930s, but since the 1970s CTC and Planalsucar (later RIDESA) have been the leading actors in the development of sugarcane varieties,

In the same period (1972–1973) the Sugarcane Technology Centre (CTC) was initiated as a joint research centre for Copersucar (the Sugarcane and Ethanol Producers' Co-operative in São Paulo state); see more in Appendix 3. It was created by Copersucar in order to maintain competitiveness in São Paulo and to break inertia (Fronzaglia and Martins, 2006). At CTC they introduced R&D programmes for the sugar industry, with R&D geared to sugarcane varieties and production technologies. One of their ideas was the policy programme of Pró-Álcool (the National Alcohol programme, Programa Nacional do Álcool), which has been crucial in creating linkages and great synergies between industries, research institutes and public

authorities in the technology, industrial policy, energy planning and agricultural production areas (T. Andrade, 2008).

In 1975, as a response to the international petrol crisis, the Pró-Álcool programme was launched. The motive was to stimulate domestic fuel ethanol supply, by aggressive market intervention through quotas, marketing orders, price setting, and subsidised interest rates (Martines-Filho et al., 2006). Ethanol prices were fixed against petrol at 60% (De Almeida et al., 2007). From 1976 to 1979 production grew from 158 to 900 million gallons (Gomez, 2007).

With the second oil shock, renewed and widened activities were introduced in order to create a system for ethanol-fuelled cars. The ambition was to achieve energy independence and to stimulate the domestic industry. The programme aimed at developing capabilities and creating necessary linkages between industries, research institutes and public authorities in the areas of technology, industrial policy, energy planning and agricultural production. In 1979 changes in the programme were introduced, such as the inclusion of tax incentives and subsidies to the industry to develop goods and technology and to get consumers to buy ethanol fuelled cars. There was co-ordination of actors to put complementary technologies in place; e.g. it became mandatory for petrol stations to have ethanol pumps (De Almeida et al., 2007). There was support to development of technology to enable cars to run on ethanol (Gomez, 2007). There were also price regulations so that ethanol prices were fixed against petrol, and petrol subsidised ethanol process, through taxes and subsidies (Martines-Filho, 2006). Ethanol was also included in the national energy plans.

The early technology was quite poor, but by 1985 it had improved and functioned properly. At the end of the programme the number of new car sales was 90% pure alcohol cars. Before the programme the capital equipment industry had quite low technological capability, but due to resources allocated to CTC and their research to develop and introduce incremental innovations to improve the efficiency of the extraction and fermentation processes from sugar syrup, the level of sugar extraction increased from 92%, before the Pró-Álcool, to 96% in the mid 1980s (Tosi et al., 2008). There were also other initiatives, such as exploring possibilities for using sugarcane as a source for plastics (Molinari, 2006).

At the same time, at the end of 1980s and in the 1990s Brazil had severe macro economic problems, and the great subsidies involved in the programme were hard to sustain with the growing economic problems and with the return of democracy (Tosi et al., 2008). Subsidies from taxation of petrol that were transferred to lower prices for ethanol were now removed. At the same time, oil prices were falling and sugar prices were rising, so consumers had less interest in running cars on ethanol and producers were more interested in producing sugar than ethanol, which led to a volatile supply of ethanol (Storel, 2006). There was unfavourable pricing for ethanol versus petrol, but also problems with supplies, which caused consumers to lose confidence in the sugar industry and in ethanol as an automotive fuel.

With the general deregulation in 1989 there came changes in the sugar industry, which led to the suppression of the IAA and Planalsucar (Martines-Filho, 2006). Their activities were continued in RIDESA (the Inter-University Network for the Development of the Sugar and Ethanol Industry, Rede Interuniversitaria para o Desenvolvimento do Setor Sucroálcoolero) and later in UNICA (A União da Indústria de Cana-de-Açúcar, The Union of the Sugarcane Industries).¹¹ UNICA recruited many of its employees from the IAA (Storel, 2006).

Pró-Álcool, which is currently regarded as a success, has been questioned. It was considered a failure by many, during periods in the 1990s and as well in early 2000s, as it was deemed not to have created a sustainable technology, but only diverted resources to sugar millers (Gordon, 2001). This was before flex-fuel cars and times when the price ratio between ethanol and petrol was unfavourable for ethanol. For some it also reminded them of the strong influence of the sugar industry on the Brazilian state (Gomez, 2007).

However, the estimations of costs and benefits from the programme imply that it has been a success. The investments in agriculture and industry for the production of transport ethanol in the period 1975–89 have been estimated at close to USD 5 billion, triggering benefits in terms of import

¹¹ It is voluntarily organised and consists mainly of the most advanced companies. Most São Paulo millers are members and in total 60% of all Brazilian millers are members. There are similar organisations in other states, such as Alcopar in Parana, SIAMIG in Minas Gerais and Sindaçúcar in Alagoas and Pernambuco.

savings with a value of over USD 52 billion for the period 1975–2002 (Goldemberg et al., 2003). This prepared Brazil for using renewable sources of energy, which currently account for 43.8% of Brazil's total energy consumption (the world average is 13.6%). The capability of the capital goods industry was strengthened; there was both an increased demand for process equipment and simultaneous research projects carried out in CTC. The centre introduced incremental innovations that improved the efficiency of extraction and fermentation processes from sugar syrup. The sugar extraction rate increased from 92% before *Pró-Álcool* to 96% in the middle of the 1980s (Tosi Furtado et al., 2008). Besides this massive demand for locally produced goods from the sugar agro-industry, there were also a number of other benefits from the programme, such as: exports of ethanol (15% of production) and sugarcane technology, machinery, distilleries, flex-fuel cars, and consultancies. The *Pró-Álcool* programme has significantly altered the production output of Brazilian mills. There was a spike in Ethanol production in the mix of sugar and ethanol at the end of the eighties, but it is still radically different from pre-*Pró-Álcool* times; see Table 7 for the change over time. Furthermore, it contributed to substantially increased yields of sugarcane and yields of sugar in production, through the development of new varieties with a better fit to different types of terrain, for mechanical or manual harvesting, depending on soil and topography, and also more fit for ethanol production or sugar production. Harvesting seasons have increased from 150 to 220 days (Ueki, 2007).

Even though the sugar industry was deregulated, it did not mean that all types of regulations were removed. In 1993 came a law making it mandatory to blend all petrol with 20% to 25% of ethanol. In 1996 an important law was passed that made it legal for sugar mills to commercialise co-generated electricity and sell it to the electricity grid. In 1997 there was further deregulation of sugarcane processes, including freight to mills and distilleries and ethanol prices (Martines-Filho, 2006) and a removal of a 40% tariff for sugar exports. By 2002 all price regulation for cane and hydrated ethanol had been removed (De Almeida et al., 2007).

As a response to fluctuations in prices the Consecana system was developed. This is a mechanism that manages sugarcane prices through negotiations

between representatives of sugar millers from UNICA and representatives of growers in the form of ORPLANA (Organização de Plantadores de Cana da Região Centro-Sul do Brasil).¹²

In the 1990s, with deregulation and falling oil prices, prices became more volatile, and competition tougher, as the competitiveness of ethanol depends on petrol prices. A large number of old sugar plants went out of business, in particular smaller units that had only had equipment for producing ethanol specifically for automotive fuel, which is harder to blend with petrol; they could not diversify production to sugar (Peixoto, 2008). There were also many mergers and acquisitions.¹³

On two occasions petrol prices have been below the level at which ethanol prices are competitive and in both instances there was lobbying of the government for support (De Almeida, 2007). As a support measure to the industry the government raised the level of in-mixing of ethanol to petrol to 32%. In other years when there have been falls in production the government has lowered blending rates (Storel, 2006).

At the same time, Cuba was losing its capacity to export and a number of countries were entering global markets, such as Russia, Eastern Europe and some Asian countries, which created new stimuli for one group of mills that had the capacity to produce sugar and to increase production for these markets (Peixoto, 2008).

Some interventionist policies remain today; for example, the cane producers in the North and North East receive a subsidy of around 20% to offset their higher production costs compared to the Centre South. This is intended to reduce migratory pressures to the Centre South (Martines-Filho, 2006). There are two new market-oriented institutions, the Inter-ministry Council of Sugar & Alcohol (CIMA) and the National Petrol Agency (ANP). Their role is to monitor and evaluate the deregulation process, also to assess at what levels sugarcane should be part of the Brazilian energy matrix, and to provide recommendations for the level of mixing ethanol into petrol, between the levels of 20–25% (Signorini et al., 2010). ANP oversees the

¹² Orplana, Organização de Plantadores de Cana da Região Centro-Sul do Brasil) organises the sugar growers (not millers).

¹³ The peak was in the year 2000 when 120 mills went out of business.

new oil derivatives market. These are also involved in the Pro-biodiesel programme, a programme that resembles Pró-Álcool, but for biodiesel. This programme also has a special focus on supporting marginalised groups in poorer regions. Much of current regulation relates to environmental impacts, and stimulating industry to use waste materials for energy. There are and will be laws in different states at different times for burning of fields, and how to use residual products. The burning of fields will be allowed for longer times in poorer states and in hillier terrain where it is harder to mechanise, and for small farmers who have no other means. It is expected that mechanisation will cause reductions in employment opportunities of around 10% of the industry's labour force (Martines-Filho, 2006).

Around 1999 came a very important breakthrough for the ethanol industry, with the flex-fuel technology, which allows a car to run on any mix of petrol and ethanol. The first technology was demonstrated in 1994 by the Latin American division of Bosch (Hessel Teich, 2006). It was a system with sensors that recognised the fuel injected. However, the cost of the solution raised the price of the car by USD 100, which prevented the further development of the technology at the time. At the same time, Magneti Marelli a Brazilian group in the Fiat conglomerate, developed a technology based on software that did not need any sensors. Over time this reduced the additional costs almost to zero, and is now the dominating technology. As oil prices rose in 2000, and the price of ethanol, due to lack of demand, was low, drivers started to make flex-fuel themselves by mixing ethanol in the petrol, and in even higher doses than the mandatory public mix (Hessel Teich, 2006). The local availability of ethanol and the demand for a flexible solution, gave enough force to the flex car enthusiasts at Volkswagen to pressure the management to adopt the technology. VW was the only remaining firm that still produced ethanol cars at the time, and it was quite easy to adapt the cars and mount the new technology. It was a tough internal fight between engineering, marketing and assembly, but in 2003 Volkswagen launched the car, which was a success, and most large brands have followed after. With the climate crisis and soaring oil prices the Brazilian sugar industry has become a huge success, and 50% of the fuel used in Brazil in 2009 is ethanol, and 94% of all cars sold are flex-fuel cars (Unica, 2010).

The production of sugarcane, sugar and ethanol is increasing, and even though the relative mix of output from mills is not as highly concentrated

on ethanol presently as at the end of the 1980s, see Table 7, the absolute volumes are substantially higher, see Table 9, and the relative mix is also higher than at the end of the 1990s.

Table 7: Brazilian mix of sugar and ethanol output over time

Year	Sugar output	Ethanol output
1969/1970	85%	15%
1979/1980	53%	47%
1989/1990	27%	73%
1999/2000	47%	53%
2008/2009	39%	61%

Source: MAPA (2009)

Currently the industry is growing, and there is investment in new areas of the country. Brazilian firms are clearly well positioned to benefit from the technology build-up in ethanol as a biofuel, in order to export ethanol, and a broad range of technology related to the sugar industry.

4.2 General Overview of the Brazilian Sugar Industry's Set-up

Brazil's sugar and ethanol agribusiness is of major importance for the country around 3.6 million direct, indirect and induced jobs (Washington Silva, 2007). The activity has a strong presence in the economies of over 960 municipalities, which represent around 17% of Brazil's total, in a permanent, decentralised job-creation and income-generation processes. The industry directly maintains more than 600 schools, 200 day care units and 300 ambulatory care units throughout Brazil. It is a labour-intensive rural activity that reduces migratory flows to the cities.

From the point of view of our study of the relation between clusters and innovation in Brazil, there is a clear tendency of clustering in the sugar ethanol industry. Approximately 80% of the sugarcane is harvested in the Centre South of the country, 60% in the state of São Paulo, where 39.2 % of formal employment is, and the other 20% is produced in the North East,

where Pernambuco and Alagoas stands for 29 % of formal employment (Ferraz, 2007). For the location of sugar mills in Brazil, see Figure 4

Figure 4: Location of sugar mills in Brazil



Source: Nipe (2010)

The lion's share, approximately 90%, of the 20.54 billion litres of ethanol produced in 2007/2008 is produced in the Centre South. The majority of the production infrastructure is also located in the region, as indicated by table 8. In the sugar industry the geographical distribution is more dispersed for sugar mills than for metal-mechanical factories, which is an outcome of the fact that it is more efficient for plants to be located at the centre of sugarcane fields, due to the logistics of bringing sugarcane to the milling. The existing 363 mills were spread over 300 municipalities (Ueki, 2007). In São Paulo in 2007 there were 169 plants in 130 municipalities. There are still notable clusters. When it comes to sugarcane production, there are five main clusters in São Paulo, Piracicaba, Jaboticabal, Jaú, Ribeirão Preto and São Joaquim da Barra. Of high importance in mills and sugarcane are Piracicaba and Monte Mor, located close to Campinas (Ueki, 2007).

Table 8: Plants and distilleries in the North East and the Centre South

Region	Pure sugar plants	Distilleries	Plants with distilleries	Total units	Percentage of alcohol production
North East	8	19	52	79	12%
Centre-South	8	59	209	276	88%

Source: MME/ MAPA (2005)

The productivity of the state of São Paulo is among the highest in the world (Fatima Vidal et al., 2006) and the highest productivity in São Paulo is in the North East part of the state (Ueki, 207). However the North East of Brazil is lagging compared to the Centre South, see Table 9. There are a number of reasons for this. One main concern, which is part of what is explored in this thesis, is the institutional arrangements and the use of technology. There are also climatic and natural concerns: the soils are not as rich, requiring more fertilisers, and need to be rested more frequently than in the Centre South. The rain is more irregular, which can cause problems for harvesting, as this cannot be done during rain, at the same time the land is drier and is in greater need of irrigation. The terrain is also hillier, which makes it harder to use mechanical harvesting. There have been estimates that in the North East there is a need for five times as many cutters as in the Centre South, since there is no machinery suitable for handling the high slopes of the North East. In São Paulo it takes 0.8 workers to harvest 1,000 tons of cane, but the North East needs 5.8 workers (Camarotto, 2009). Furthermore, it seems as if there are more small-scale producers that have lower technological capabilities and produce lower volumes with older technology (SEBRAE, 2007). In addition, representatives of the industry complain that they have to work with VAT levels of 25% in Pernambuco and 27% in Alagoas, as compared to 12% in São Paulo (SEBRAE, 2007). With these facts in mind, it is still the case that in the North East production is more productive than in most places of the world, and individual locations have as high productivity as some of the most productive places in the Centre South.

Table 9: Production of sugarcane (tons) and productivity (tons/hectare) in Brazil

	Brazil		São Paulo		Alagoas		Pernambuco	
	T	T/ha	T	T/Ha	T	T/Ha	T	T/Ha
1990	262674	61.5	137835	76	26151	47	22818	49
1995	303699	66.6	174960	77	21573	48	20665	49
2000	326121	67.9	189040	76	27798	62	15167	50
2005	455272	73.8	266071	81	23991	61	18832	51

Source: Secretaria de Política Agrícola – MAPA, Agricultura Brasileira em Números Anuário2005 <http://www.agricultura.gov.br/pls>

Note: The population of Brazil is 190 million, São Paulo 41 million, Pernambuco 8 million and Alagoas 3 million.

It is estimated that the sugar cane growing, sugar and ethanol processing creates around 950.000 direct jobs (Ferraz, 2007), but in a broad sense creates around 3.6 million jobs, of direct, indirect and induced jobs (Washington Silva, 2007). There is a process of change towards an increase in the number of jobs being formal, and agricultural jobs are being reduced while industrial jobs are rising. On average, including salaries and benefits, employees in the sugarcane industry receive 3.5 times as much as the country's minimum wage on farms where workers have low qualification and education levels, and 5.3 times as much in the industries. Benefits include medical, dental and pharmaceutical care, life insurance, meals, food and transportation stamps, private pension plans, school aid, breakfast, and access to credit co-operatives (da Graça, 2006). In both the Centre-South and North East regions the income of people working in sugarcane crops is higher than in any other crop, except soybeans (highly mechanised), and salary levels for people working in harvesting are higher in the Centre South, which often experiences labour shortages, according to our respondents (Santos, 2008).

Agricultural producers, most of whom are small-to-mid-sized property owners, are paid according to a parametric formula that takes into account the total sugar content of the raw material and the prices for sugar and ethanol in both domestic and export markets. The amount paid for

sugarcane in Brazil represents 60% of the industry's turnover (Roque de Oliveira, 2008).

The trend is that firms are locating westwards in São Paulo and in Minas Gerais, where old cattle land is taken over, and also in the south and west of the country. There are both investments from established actors that are growing, and new actors entering, such as firms from the North East, investments from completely new groups and foreign actors Luis Dreyfus and Telus locating here (Zylberstajn, 2006). Large European firms are interested in investing as they are about to lose their protection in Europe and Brazil has superior opportunities. There is also an interest to invest in order to learn more about Brazilian technology. The investments are stimulated by favourable government policies that provide funding to set up plants and to mechanise harvesting. There is also a tendency of mergers and acquisitions among millers; from 1995 to 2005 there were 35 acquisitions. At the same time the relative concentration of firms in the country has not increased (Vian et al., 2005).

Brazil exports more than 50% of its sugar, and 15% of its ethanol (Martines-Filho, 2006). Exports took off only in the last decade, first due to high tariffs preventing exports, then later due to the fiscal stabilisation programme of Plano Real, which kept the exchange rate so high that it prevented exports (Tyler and Costa Gurgel, 2007). If the US and EU removed trade barriers and zeroed out subsidies, there are estimations that the value of agricultural and food output could increase by 34% and real net farm income by 46%. In other scenarios developed by the World Bank, Brazil's income could rise by USD 3.6 billion a year. This is why Brazil is eager to succeed with lowering barriers to agricultural trade in the WTO negotiations (Economist, 2005). Brazil has actually decided to unilaterally remove its tariffs and quotas on sugar by the end of 2011, as a means to show the way to other actors (Dow Jones, 2010). Still local demand for ethanol is very high and important.

Brazil also has a potential for the industry to grow. The total agriculture in Brazil occupies 60 million hectares, which could expand by another 90 million hectares without touching the Amazon rainforest, according to Silvio Crestana, director of Embrapa (Empresa Brasileira de Pesquisa Agropecuária, Brazil's federal public company for agricultural research)

(Economist, 2005). In 2006, 74.1% of all agricultural land was used for pastures; whereas only 3% is used for growing sugarcane (IBGE, 2006).

Even though government has abandoned price regulation there are still a number of measures implemented to stimulate industry. For example, the ethanol industry receives an advantage from tax subsidies, due to which it can keep competitive prices compared to petrol; e.g. ethanol is not charged an excise tax, and in some states like São Paulo, Paraná and Rio de Janeiro the VAT rate is lower than for petrol. The biggest difference is in São Paulo, where 47% of the price of petrol is taxes, whereas for ethanol it is 22%. The same figures for Rio are 50% and 36% (De Almeida et al., 2007).

The federal government provides funding for innovation projects in private firms, collaborative projects between firms and university, and funding for research projects. In 2005 the MCT (Science and Technology Ministry) invested USD 840 M in total R&D, of which 21% went to agriculture-related research (USD 176 M) (IADB, 2007; Amaral, 2008). FINEP, which is a part of the Ministry of Science and Technology, was created in 1967 (before MCT, which was founded in 1990) with the role of financing R&D, S&T and innovation in firms, universities, institutes and research centres to promote the social and economic development of the country. FINEP has financed the setting-up of EMBRAPA and much of the activities of the agricultural industry in Brazil. Embrapa has not undertaken much activity within sugar, though, as there were well-established research centres in place, such as the IAC (funded by the São Paulo State government), the Planalsucar research programme and the CTC (Inovação Unicamp, 2006a). Another unit of the MCT is the National Council for the Development of Science and Technology (CNPq, Conselho Nacional de Desenvolvimento Científico e Tecnológico).

Furthermore, the ethanol industry receives subsidised credit lines targeted for Brazilian agriculture, and long-term credits from the National Bank of Social and Economic Development (BNDES) for industrial development such as ethanol projects. These credit lines are substantially cheaper than credits from private banks. However, interest rates in Brazil are in general very high, so these levels are more than the international average (De Almeida et al., 2007). There are also tax incentives for technological innovation, by Bill no. 11,196, of November 21, 2005, that allows firms to deduct double the investment in R&D. Bill no. 10,973, of December 2,

2004, also-called the Innovation Bill, has a subvention mechanism where it can provide financing with a forgiveness clause directly to private companies. In 2008, however, not many were using these schemes; a major survey of innovation activities in Brazil, Pintec 2008 (IBGE, 2010), found that neither of the bills has had a large impact; only one firm involved in ethanol production out of 204 surveyed had utilised it, and 38 out of 5551 firms in the machinery and equipment sector.

Then there are BNDES programmes for funding R&D and innovation, a programme that finances the industrialisation stage of technological inventions and BNDES FINAME which provides financial support to producers of national equipment and machines, but also to purchasers of national equipment (BNDES, 2010a; 2010b). They have also the Technology Fund (FUNTEC – Fundo Tecnológico) to support technological development and strategic innovations in Brazil (MDIC, 2010).

The Innovation Bill's target group is micro and small businesses and the subvention is made through the Science and Technology Ministry's (MCT) innovation agency (Finep) and through partnerships between Finep and the different state innovation fostering agencies, such as São Paulo's research foundation FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo). Finep also provides a line of measures for small technology start-ups and loans to innovation in micro and small businesses. There are also many state and local initiatives, as we will see in the following section.

According to the Pintec 2008 survey, for the ethanol producers, the most important programmes are the ones that finance purchase of equipment, for which 18 % of the innovating firms (94 in total) out of Brazilian ethanol producers (204 firms) received financing. In total 26% of innovators received some policy support.

4.3 São Paulo/Piracicaba Institutional Set-up

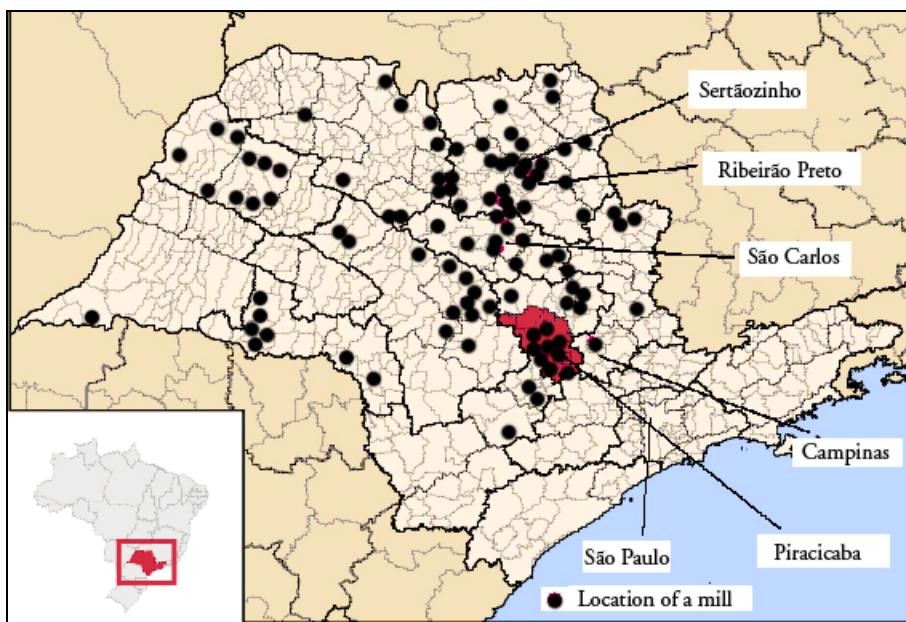
The most important state in Brazil when it comes to the sugar industry is São Paulo, which has the best natural conditions, the most important research institutes, the greatest presence and diversified industry structure, with metal-mechanical industry, and the greatest number of sugar and ethanol mills.

The best natural conditions for the sugar industry are in São Paulo, where there are very rich soils that allow for many years of harvesting without resting, there is a good temperature for growing cane, and there is not so much rain that prevents harvesting, which allows for a long season of harvesting. There are great possibilities for artificial water systems. The land is in general not very hilly, which makes it easier to harvest and in particular to use mechanical harvesters.

São Paulo is the most industrialised state of Brazil, which has benefited the development of the industry around sugar processing technology. In São Paulo the complete value network is present. There are numerous sugarcane plantations, sugar and ethanol factories, research institutes and metal-mechanical industries. The most important clusters in the state are Piracicaba and Ribeirão Preto, with the nearby town of Sertãozinho. The former is more institutionally thick with more R&D capabilities, metal-mechanical industries, while the latter has more and larger sugar and ethanol production facilities, important production of harvesting machines and the soil is more productive around Ribeirão Preto (Zylberstajn, 2006). There are three other locations that are up and coming: São Carlos, the North West corner of São Paulo and the West (Roque de Oliveira, 2008). Campinas and São Paulo are also important locations in the state, Campinas being the large university town with much R&D and São Paulo the industrial and financial centre and the state capital with much political influence. For their location see Figure 5.

One could choose to observe all of São Paulo as a cluster or to focus on these sub-regions in the state. In this thesis we have a particular focus on Piracicaba and will describe this cluster in more detail; at the same time we will analyse relations that are outside the local cluster, at state and national levels. Whereas the clusters in most other parts of the country more resemble what Markusen (1996) refers to as Hub and Spokes clusters, where the refinery is the dominant actor in the cluster, the cluster in Piracicaba is more levelled due to the large number of actors. There is also a cluster initiative called APLA (Arranjo Produtivo Local do Álcool da Região do Piracicaba, the local production arrangement launched for alcohol in the region of Piracicaba), see Appendix 4.

Figure 5: Alcohol and sugar factories in the State of São Paulo and important location



Source: <http://www.cidadespaulistas.com.br/prt/map-tematico/mp-usinas-alc-acucar.htm#>

Piracicaba is a city of 350,000 inhabitants. It is the 19th largest city of the state of São Paulo, but the 5th most important when it comes to exports. It is located in one of the most industrialised and productive regions of the State of São Paulo. Piracicaba is located in the centre of the state of São Paulo and two hours away from the city of São Paulo, see Figure 5. Piracicaba is institutionally thick and has renowned research institutes and firms. There are seven R&D institutes in physical and natural science, 18 for higher education, and more than 20,000 students, and there are 9 institutions for vocational training.

The city has approximately 70 firms that produce equipment for the whole production chain of ethanol and sugar. The most well known company is Dedini (see Appendix 2), renowned for turnkey sugar and ethanol distilleries in most sizes both for national and international markets. Other notable metal-mechanical firms in Piracicaba are NG Metalurgica (1,500

employees), Mause Equipamentos Industriais (500 employees) and CSJ Metalúrgica (co-operative with 250 shareholders and 450 employees). There are 11 refineries in the region and in the surrounding fields approximately 17 million tons of sugarcane are harvested on a yearly basis. This is used to produce 1.4 million tons of sugar and 502 million litres of ethanol per year. The most important actor is the Cosan group, see Appendix 1. They are one of the world's largest producers of sugar and ethanol and they own 17 mills, of which four are located in Piracicaba. Many of Brazil's leading firms are located in Piracicaba and in the State of São Paulo, and besides Cosan there is also Crystalsev, which has been bought by the French commodities group Louis Dreyfus and is now known as LDC-SEV, one of the world's largest sugarcane processing companies. Also located there is Copersucar, which started out as a collaborative effort by ten companies to strengthen marketing and sales of primarily ethanol and sugar with the joint consumer brand União (Ueki, 2007). It went on to create its own R&D lab, the CTC, which in 2004 was opened up to membership of other sugar industry stakeholders. Today it is Brazil's largest sugar, ethanol and bio-energy producer. The members of Copersucar consist of 39 mills, see more in Appendix 3.

The city is seen as the national technology centre for the sugar and ethanol industry, with renowned educational institutions with more than 20,000 university students and important centres of research and technology. Located in the city is the Agricultural College Luiz de Queiroz (ESALQ), which is Brazil's first and most important agricultural school, and the largest university campus of agriculture in Latin America. It offers undergraduate and graduate courses in Agriculture, Forest Engineering, Economics and several other areas and undertakes substantial R&D. The Pró-Álcool programme has parts of its origin in this institute and in CTC (Izique, 2006). Also located in Piracicaba is the Sugarcane Technology Centre (CTC), which is the country's first and largest private R&D institute to develop new agricultural, logistic and industrial sugar technologies, as well as to develop new varieties of sugarcane. Through CTC and ESALQ, organisations in Piracicaba are well connected throughout Brazil, both through formal networks and through informal and personal networks (Vian, 2006). Other important academic institutions of importance are the Centre for Nuclear Energy in Agriculture (CENA), the School of

Engineering of Piracicaba (EEP), the Methodist University (UNIMEP) and the elementary education COTIP.

Besides these there are also a number of providers of specialised services such as the consultants Bioagri and Fermentec with core competences in research and knowledge of fermentation, sugar and alcohol production. Furthermore, there are suppliers of experimental equipment and technical support, e.g. Marconi and Tecnal (Ueki, 2007).

In the Municipality of Piracicaba, the local government together with the local industry and R&D institutes has launched a cluster initiative in order to strengthen the competitiveness of the local industry. The cluster initiative is called the *Arranjo Produtivo Local do Alcool da Região do Piracicaba* (APLA), see Appendix 4. The APLA seeks to address challenges for all of the sugar value chain. This makes this cluster initiative different in Brazil, as most other cluster initiatives consist of mono-product micro firms. The APLA consists of SMEs, but also large firms, producers of raw material, machinery, and distilleries. The theoretical knowledge about the importance of a trustworthy social entrepreneur was confirmed in the case of the APLA (Andersson et al., 2004). The leadership of the cluster initiative by Luciano Santos Tavares de Almeida has been crucial for the development of APLA, as has been emphasised by a number of respondents (Stipp, 2006; T. Andrade, 2008; Castelar, 2008). Santos has an industrial background, through which he has managed to convince both private and public actors to participate in the project. The process has been both top-down and bottom-up. SEBRAE (Serviço de Apoio às Micro e Pequenas Empresas, the Brazilian Support Service to Micro and Small Enterprise) has assisted in initiation and catalyzing processes, but the formulation of needs, goals and activities has been carried out by the participants. They have set up a number of groups of strategic activities, such as export journeys and visits to trade fairs, lobbying activities and local study tours for visitors. There is also an establishment of a technology park, Parque Automotivo, in which there will be further development of new technologies related to biofuels, as well as construction of cars. The park will host car manufacturing, as well as research and education (Jornal de Piracicaba, 2010; Portal do Governo do Estado de São Paulo, 2009).

An important agency in São Paulo for the development of new technology is the State of São Paulo Research Foundation – FAPESP. It has worked with

a number of programmes to support innovation. One of the major programmes has been the PIPE programme (Technological Innovation in Small Business Programme (Programa Inovação Tecnológica em Pequenas Empresas, PIPE), which was initiated in 1997. It has supported over 700 research projects (FAPESP, 2007) in small businesses in the state of São Paulo with non-refundable investment. Among other things, PIPE has financed the development of both bioplastics, PHB and the start-up of a firm around it (Molinari, 2006). Furthermore, FAPESP has the Partnership for Technological Innovation research programme (PITE), which was set up in 1994. The objective is to stimulate partnerships between universities, research institutes and businesses. It does so in two ways: i) researchers from universities and institutes create joint projects with industry which is co-financed by industry and FAPESP; and ii) PITE agreements, whereby FAPESP sets up a thematic programme with a firm to support a range of projects; funding comes from the firm and FAPESP. The projects in the programme are opened up to call for proposals that can be addressed by researchers from universities and institutes. These types of agreements are in place with Dedini (signed in 2007 with a value of around USD 53 million), where there is a programme to support research into industrial processes for the manufacture of ethanol from sugarcane. There is also an agreement with Oxiteno to support research in the areas of alcohol chemistry and sugar chemistry (signed in 2006 with a value of USD 3 million) (FAPESP, 2007).

In the last few years with the boom in the sugar industry, there has been a great need for labour for both the metal-mechanical industry and the sugarcane and processing industries. The city has been growing steadily and there have been problems with labour shortage. To meet these problems there have been campaigns to attract labour from the North East and also to capacitate unemployed people from São Paulo (Santos, 2006; Sartori, 2008).

The terrain around Piracicaba is not optimal for the production of sugarcane as it is too hilly for mechanised harvesting in some places, and many expect that in the future the production of cane will decrease in the region. Mechanisation will come both due to efficiency, but also as the practice of burning cane will be prohibited. In 2002 it was regulated that the burning of fields during the harvest process was to be phased out, in areas above 150 hectares, for terrains with a slope lower than 12% by 2021 and for greater than 12% by 2031. However, a voluntary agreement between the government, the sugar and ethanol industry and ORPLANA, that they will

stop burning, by 2014 for lower than 12% terrain and by 2017 for the steeper terrain. Furthermore, newly established plantations will not do any burning. These changes will most likely quicken up mechanisation of harvesting processes. Mechanical harvesting will require more skilled labour, of which there is presently a lack. The state government and other public resources are addressing this, both through technical colleges and in vocational training (Santos, 2008). Also, the syndicates (Roque de Oliveria, 2008) are planning for requalification of personnel, partly through the Rural Educational Service (SENAR, Servicio Rucional Apprendisage Rural). At the same time there are a number of metal-mechanical firms that would respond positively to this, such as CASE, Santal, Motocana and John Deere.

The price for ethanol from São Paulo is also affected by the geographical location. Most of the cane, sugar and ethanol is produced inland, and the infrastructure is still not optimal; in comparison to the North East it is a longer distance for exportation, which puts a cost premium to the production in this location. One way to address this is the creation of an industry consortium called Uniduto Logistica to build a pipeline for ethanol (Uniduto, 2010).

Piracicaba's institutional thickness and critical mass of actors from a broad range of the sugar value chain has positioned Piracicaba as the national centre for biofuels, which has also received much international attention with prominent visitors, such as Bill Gates and the founders of Google (Castelar, 2008).

4.4 Brazilian North East Institutional Set-up

The North East consists of nine states (Alagoas, Bahia, Ceará, Maranhão, Paraíba, Piauí, Pernambuco, Rio Grande do Norte and Sergipe). The two most important states for the sugar industry are Pernambuco and Alagoas, see Figure 3. Pernambuco was the first sugar region in the country, but is now contracting, and Alagoas is the quickest growing sugar region in the North East, but will soon have met its limits. The North East is the poorest region of Brazil and its economy resembles a developing country more than the state of São Paulo, which in many senses is highly developed. There are large problems in the North East with unemployment and sub-employment, poverty and illiteracy.

Pernambuco used to be the primary state for sugar production. The location of the sugar industry in the North East was due to natural factors, both the possibility to grow sugarcane and to process sugar, and the relative closeness to Europe which provided a market for the sugar colony to expand. Most mills are also located in the coastal areas of Maceio and Pernambuco, see Figure 4. Later, when these markets either disappeared or decreased in importance, as the importance of the national markets increased and in particular the Centre South of the country, the North East lost in importance as a productive region.

Depending on how one draws the geographical limits, one can say that the entire region is one large industrial cluster, but one could also call the different refineries and closely located refineries clusters, and these are more similar to Hub and Spokes clusters, where the refinery dominates the region. Refineries are in a strong position vis-à-vis sugarcane growers who deliver sugarcane to them.

As described in the historical introduction, Brazil experienced sluggish growth up to the end of the 1960s. In a programme to revitalise the economy, efforts were launched to restructure the sugar economy. Out of this came the programmes of Planalsucar and Pró-Álcool, which was initiated by groups in the Centre South, but it also benefited the North East. The region's total production grew until the 1990s, and from the harvest of 69/70 to 89/90 sugarcane production in Pernambuco more than doubled from 9.6 million tons to 21.9 million tons; in Alagoas the numbers were even more impressive and the state outgrew Pernambuco as it increased its production fivefold from 5.7 million to 26.4 million tons of sugarcane. Sugar production rose from 0.5 million tons in Alagoas to 1.2, and in Pernambuco it rose from 0.9 million to 1.3, and due to the Pró-Álcool programme ethanol production increased from levels that had been insignificant, 0.03 million litres in Alagoas to 0.9 million and 0.08 in Pernambuco to 0.6 million (Mapa, 2009).

It is likely that the measures aimed at stimulating the sugar economy in this period, with tariffs, quotas and subsidies, made the sugar economy in the North East, and in particular in Pernambuco, grow more than was sustainable with regard to land use.

At the end of the 1980s much of previous government protection of the industry was gradually removed. As a result the sugar industry contracted,

particularly in Pernambuco. During the 1990s there was a period of structural adjustment and around 20 mills of 43 were closed. Around 150,000 jobs were lost in the industry from 1987 to 2007, adding a burden to a regional economy that was already suffering from losses of jobs for unskilled labour. In the North East 35% of total employment, or around 300,000 persons, are related to the sugar industry and 10% of GDP comes from the sugar industry (Morais de Andrade, 2007). Pernambuco has been surpassed by Alagoas with its 25 mills, as the dominant state in the North East (IDEA, 2007). The firms in Alagoas have been better at adapting new technologies and methods, while many of the firms in Pernambuco are old family firms that have had financial problems since the 1990s and have not upgraded to the same extent (A. Andrade, 2007).

A characteristic which is of particular importance in Pernambuco is that much of the land is too dry and as much as 75% of the terrain is hilly, and it receives rain irregularly. The rain stresses the sugarcane and makes it harder to harvest, there is also less potential to make irrigation systems and to use mechanised harvesting. In Alagoas these problems are not as notable, and for example 65% of the plantations are irrigated (Evangelista, 2007). In farms with favourable soil, flat lands with access to irrigation, and utilising modern technologies and improved sugarcane varieties, they reach productivity levels that are similar to the best ones in the Centre South (A. Andrade, 2007). Notable mills are the Usina Olho D'Água in Pernambuco and the Usina Coruripe in Alagoas. The latter are members of CTC, and their director is also vice president of CTC, see more in Appendix 3.

Production in the North East was more widely spread before and was carried out in more parts of the hilly and dry land. With current price levels, technologies and production processes, Pernambuco has most likely met its limits to how much land can be used. Many firms are establishing themselves outside of the state, operating multiple plants, while some are moving out completely and bringing equipment with them. Alagoas is not that far away from reaching its limits, even though there remain some possibilities in the north of the state. There is some land between Alagoas and Pernambuco, the Cegipe that could potentially be expanded, and also if there is an investment in an irrigation and canal system in the Sertão inland of the State of Pernambuco, about which there is currently discussion between Petrobras (Petróleo Brasileiro, the Brazilian public petrol company) and the Japanese government (SEBRAE, 2007). Some of the respondents

argued that they see it as unlikely that it will come about or that it would be possible to use for sugarcane growth (Almeida, 2007; T. Andrade, 2008).

The clusters in the region are not as dense as in the Centre South, but still they consist of a variety of actors, with the centre composed of the sugar and ethanol refineries and sugarcane growers. There is some limited inter-firm collaboration and between firms and universities on issues such as R&D, infrastructure through industry organisations and lobbying, but to a much lesser degree than in the São Paulo region. There are also some notable research facilities, such as the Federal University of Alagoas (UFAL) and the Federal University of Pernambuco (UFPE), which are part of RIDESA. In Alagoas UFAL has a notable experimental station in Serra do Ouro that produces seedlings for sugarcane development. In Carpinas UFPE has a station that develops new varieties and natural pesticides, such as protective insects. Carpinas is jointly owned by UFPE and Sindaçúcar (the Union of Sugar and Alcohol Producers in Pernambuco). Furthermore, both CTC and Cana Vialis have research stations in the North East as well (Ueki, 2007).

There is some metal-mechanical industry in the region, such as branch offices of Dedini in Alagoas and Recife (Ueki, 2007), and the local firm, Implanor, that has developed a sugarcane collector, which is particularly apt for the hilly terrain that dominate Pernambuco. There is the enzyme company Bioenzima that produces enzymes for different industrial process, such as enzymes for treatment of denim textile.

However, there is currently no general collaboration between government, industry and academia, such as in São Paulo where there are programmes for vocational training of laid-off sugarcane cutters, which could be one approach to facilitate restructuring through retraining of sugarcane cutters into machine operators (A. Andrade, 2007; Almeida, 2007).

In the North East independent cane growers are worried that there will be a concentration of the industry, with the large millers buying all the land and becoming self-sufficient. There are investigations indicating that currently in the North East 70% of cane is grown by the millers themselves and that this process of vertical incorporation is increasing (Fatima Vidal, 2008). The sugarcane growers association is lobbying for a law making it mandatory for sugar plants to buy at least 40% of their cane externally (Moraes de Andrade, 2007). At the same time, some of the millers that we interacted with said that they do not want to produce all of the cane themselves as there is a

danger in over-production in bad years, and that it is a sort of risk management system to be able to buy from external sources (Neto, 2007).

There are protective measures in place to reduce the competitive pressures on the North East. The region is less economically developed than other parts and there is a fear that the region could not handle full deregulation and that the important sugar industry would decrease beyond levels manageable by the local economy. To compensate for a lack of competitive production, the federal government has awarded the North East the Brazilian sugar quota to the US (Bolling and Suarez, 2001). The quota is not a major share of the total export, but beneficial for the region that exports 50% of its production (Cortez, 2007; Evangelista, 2007). Growers in the North East are also receiving a subsidy of BRL 5.00 per metric ton of sugarcane up to 10,000 metric tons per grower for sugarcane produced during the 2009/2010 crop, in order to balance the difference in cost of production between the Centre South and the North East (USDA, 2010).

There are also a number of public programmes in place to stimulate innovation and upgrading. Available to firms in the North East are programmes like FINAME, Inovação and production (BNDES, 2010a, 2010b), but there are also federal programmes for innovation and upgrading that is targeted particularly towards the North East, from FINEP (receives funding from BNDES and the Science and Technology Ministry (MCT)) that finances loans for investing in sugar mills, as well to increase mechanisation, of which 30% of the funds are targeted for the North, North East and Centre West.

There are also regional financing schemes and actors that manage federal funds. Banco do Nordeste (The North East Bank) has specific funds for small and micro firms that are about to innovate, called the Financiamento do Nordeste Inovação; half of the funds are for the agricultural industries. Banco do Nordeste also has the programme O Cresce Nordeste, which provides loans for modernisation of agro-industrial plants, new processing practices, introduction of new products and exportation of products from the sugar and ethanol industry (Banco do Nordeste, 2010a). They also finance research projects.

Even though in many respects the region has a geographical disadvantage it also has some advantages: the proximity of sugar mills to consumer centres and exportation, as most producers are located close to the coast, with

relatively good infrastructure, only 100 km on average compared to 500 km in the Centre South (Fatima Vidal, 2006), and the region is located closer to the EU and the US. Their transportation costs in order to ship to these markets are lower than for the Centre South, and with the EU removing its sugar tariffs in 2011 this could be an important opportunity.

The sugar industry is causing environmental problems from leaking residuals such as vinasse and air pollution from burning cane fields. The government has addressed these problems by prohibitive legislation. The ban on burning of fields has made the sugarcane producers and in particular the mills indicate that they will turn to mechanical harvesting. So far growers have abstained from this, due to the problems of the terrain and lack of appropriate equipment for it, and also as a deal with labour unions and government in order to save jobs (de Santana, 2007; Almeida, 2007). At the same time there are government programmes that provide loans to mechanise, such as from FINEP and FINAME. However, there is a lack of skilled people to operate and maintain machines at the moment, at the same time as much unemployment will be created. There are discussions about the needs for retraining programmes (Almeida, 2007).

Most refineries use seasonal workers during harvest, who come from the dry lands in the interior of the state. These are small scale farmers who cannot farm their own land during the dry seasons and travel to the coast to work in the sugar harvest. The work is considered tough, but well paid by the standards of agricultural harvesting. There is also a trend to employ fewer people from the vicinity. One of the respondents justified this in terms of problems with the non-appearance of local labour; seasonal workers are more motivated and focused on work (T. Andrade, 2007). Also, there are still occasions of labour abuse even though the incidents have radically decreased according to the labour union; they say it is not a major issue any longer, but that cutting sugarcane is a good job (de Santana, 2007).

Sugar is very important for the labour force, but it is a decreasing opportunity, as the industry is shrinking. At the same time, there seems to be a viable future in the North East, but in a smaller costume than previously. Rural unemployment has risen, and at the same time opportunities and employment has grown in the bigger cities. Even though Recife and Maceio, the capitals of the regions, are growing, the region itself is troubled with large numbers of sub-employed people and low education

levels. Therefore there are also large numbers of people moving south, where salaries are better and where there are greater labour opportunities.

4.5 Historical Introduction to Cuba's Sugar Industry

The sugar industry in Cuba began in the region surrounding Havana. In 1576 three *Ingenios* (*engenho*, i.e. a simple mill with crushers operated by cattle or water power), were established there. The sugar industries in Cuba, grew out of its soils and climate which are favourable for sugarcane production. Also, the relatively close location to European and American markets has favoured the sugar industry in Cuba over the years. Being an island, there have not been any great distances to transport products to a harbour for export, which has also stimulated the growth of the sugar cluster.

The ramping up of the industry began at the beginning of the 19th century and became a cornerstone of the Cuban economy. Rising living standards and the size of world population increased the demand for sugar. In 1820 the world production was around 400,000 tons, in 1895 it was 7 million tons, and in that period Cuba's production rose from 55,000 tons to about 1 million tons. The rise was even greater between 1895 and 1925, when world production rose from 7 to 25 million. In the same period Cuba's sugar production had grown to more than five million tons, representing around 20% of the total annual world production of cane and beet sugar output and 36% of the total sugar production from cane. Despite being a small economy in the Latin American context, in the sugar world it was a giant. Cuba was responsible for such a large proportion that it could affect the market by volumes and prices. Not until the 1960s could anyone else compete with Cuba, when production in the USSR, Brazil and India had risen. In these countries most of the production was consumed locally, whereas Cuba exported up to 90% of its production (Pollitt, 2004).

By 1959 the sugar industry began to stagnate, and exports seemed to be flattening out. At the same time came the revolution. One of the first changes was a land law that made 75% of the land governmentally owned. Some 1,500 private farmers owned the rest (Fernandez Dominguez, 2006). Initially there were efforts initiated to diversify the industry and to upgrade

it with new technologies following an import substitution model (ISI). There were great challenges and production was almost knocked out.

In 1963, the Cuban government gave up the ISI ambitions and focused on recovering the sugar industry and developing it further. The idea was that the incomes from the renovated sugar industry would create resources for a renewed and more selective industry programme, with a new infrastructure, operated and managed by a better educated labour force (Alvarez and Pena Castellanos, 2001).

An early result of the revolution was a large movement of people away from the countryside and the sugar industry to the cities. At the same time, the new agreements with the Soviet Union offered high potential incomes to Cuba due to beneficial payments for sugar, and to grab this opportunity, new ambitious goals for the sugar industry were set up. To meet this, there were campaigns to mobilise labour for harvesting seasons, and also an effort to mechanise harvesting. In the 1960s there was an increase in the mechanisation of collecting and loading cane, which became highly mechanised; mechanical cutting took more time and did take off in the end of the 1970s (Pollitt, 2004).

There were political campaigns launched to motivate people to help the revolution and participate in the harvesting process, when there was an increased need of cyclical labour. The most famous campaign was the one for the harvest of 1970–71, when the Cuban government launched a nationwide campaign to mobilise the country for the largest harvest ever, with a goal of 10 million tons of raw sugar, double the amount of the 1950s. The campaign's official slogan was “*¡Los diez millones de que van ... van!*” (The ten million must go ... go!), a way of saying that the goal was certain (Alonso-Pippo et al., 2008). The campaign was a catastrophe, as all Cuban resources were dedicated to reaching the goal, which caused all other industries to suffer. It also fostered practices in which long-term perspectives were lost in order to reach the immediate goals; e.g. young cane was cut that should have been saved for coming years. The milling season was prolonged for 4–5 months, which caused it to go into the rainy season, with increased losses in the production process and a decline in sugar quality. This also disturbed the cycle for the maintenance and repair of mills, which caused further problems for the following harvests. Despite these problems these short sighted practices continued for a number of years (Alonso-Pippo et al.,

2008). Most problematic was possibly the creation of a culture of producing sugar regardless of costs. This culture was strengthened by the trade agreements with the Soviet Union, which offered subsidised prices for agricultural inputs, and also agreed to pay substantially higher prices for Cuban sugar than world market prices.

Cuba was part of the COMECON¹⁴ from 1972 until the end of the Soviet Union. This was a very advantageous arrangement for Cuba, as it received very high prices for its sugar compared to world market prices from the Soviet Union and the COMECON countries. Between 1985 and 1989 over 65% of Cuba's average exports of 4.7 million tons per year went to the USSR and Eastern Europe. In 1989 the COMECON price was three times the levels in the international markets. In these years earnings from sugar represented 75% of all Cuba's export earnings (Pollitt, 2004). It could also buy fertilisers and metal-mechanical components and machinery at subsidised prices. The financing allowed for mechanisation and fertilisation to equal amounts as the US and double or triple the rest of Latin America (Fernandez Dominguez, 2006). During the 1970s and up to the 1980s the sugar industry expanded and the growth model was mainly of an extensive kind, with increased land use, but also to some extent with increased cane yields. At the end of 1973 1,421 thousand hectares of land was used and in 1982 it was 1,752.1 thousand hectares. In 1971–1975 cane yields were around 43 tons/ha and rose to 54.2 tons/ha at the end of the 1980s. The increase in the yield came from increased use of agro-chemicals such as fertilisers and irrigation of the land.

In the 1980s the Cuban mills ground almost 70 million tons of cane per year (Pollitt, 2004). Cuba earned a high profit despite heavy use of imported inputs, low labour productivity and organisational inefficiencies (Pollitt, 2004). At the same time there was innovation and upgrading of the industry, such as a development of the capacity for science and technology, a metal-mechanical industry, mechanisation of harvesting, and development of a number of new cane varieties (Alonso-Pippo et al., 2008).

¹⁴ The Council for Mutual Economic Assistance (COMECON), was an organisation for economic collaboration between the socialist countries of the Eastern Bloc and a number of communist states elsewhere in the world. It existed between 1949 and 1991 and was a response to the formation of what later became the European Union.

However, in this upgrading process, despite the knowledge build-up and the mechanical and industrial capacity to build more advanced boilers, and strong financial support, few new mills were built (only eight) and there was also little renovation of existing ones. Knowledge of how to produce a number of derivatives from the sugar industry was developed, but these were hardly utilised and have had little economic importance for the Cuban economy (Monreal, 2004); for example, only eight mills were upgraded with capacity to produce electricity for the grid, and there has hardly been any ethanol for fuel production at all (Alonso-Pippo et al., 2008).

When the Soviet Union fell, Cuba lost all its advantageous market deals and large shares of its external incomes; besides the high prices paid for its products, they had also received a yearly subsidy to handle the Cuban budget deficit of around 2 billion pesos (Pollitt, 2004). In 1993 a Special Period of economic crisis was proclaimed; initially much hope was pinned on the sugar industry as a saviour of the economy, and much pressure was put on the leaders of the ministries connected to the sugar industry. However, these have since then struggled to deliver the desired results. In Cuba there have been great problems in producing sugar efficiently, and the cost-benefit ratio of production costs and world market prices made it cheaper to import sugar than to produce it (Alonso-Pippo et al., 2008). Furthermore, there have been problems producing enough sugarcane, and production volumes have steadily dropped.

A number of scholars have emphasised that the greatest problem in Cuba is the low production of sugarcane (Pollitt, 2004; Nova, 2006, 2008). From 1992–2000 the yields averaged 30–35 tons per ha but rarely surpassed 35 tons per ha, which was substantially less than the average yield of over 54 tons secured in the 1980s. The low yields were a result of a drop in fertilisers, over usage of land, without crop rotation, and the irrigation capabilities had become insufficient. The planting and weeding began to use inferior mixes of cane varieties. Furthermore, there was a drop in the availability of mechanical machinery and repair components. The industry was also inefficiently organised and had problems with incentives for labour and producers. Before 1991, people employed in sugarcane harvesting, received important incentives, such as houses, cars, tourist trips to Russia or other European Eastern countries, home furnishings, resort stays at the best beaches and last but not least preferential wages. After the collapse of the Soviet Union these incentives disappeared (Alonso-Pippo et al., 2008).

Furthermore, there have also been incentives problems due to Cuba's dual currency system,¹⁵ whereas payments to sugar farmers have been in the national currency, whereas some input factors have to be bought in convertible pesos (Dominguez, 2004). Furthermore, farmers can trade products in the free markets or through informal channels and receive much better payments, and payments in convertible pesos, which is much desired. These problems were exacerbated by state pressures for production to meet needs of foreign currency; these pressures led to harvesting of immature cane, which affected the following years' harvests, as the average maturity decreased (Alonso-Pippo et al., 2008).

In 1997 the country had such acute problems that it received aid from the FAO that provided assistance in technology and strengthened producers to increase internal production (Fernandez Dominguez, 2006). In the same year the minister in charge of agriculture (MINAG) and the one for the sugar industry (MINAZ) were replaced. The new administration of the ministries, along with a period of decentralisation in the Cuban economy, enabled the industry to better meet its objectives. Land was transferred from the government to the private sector so that 75% of the land was in the non-state sector, including UBPCs, cooperatives that do not own but usufruct state land (Fernandez Dominguez, 2006). The new leaders prohibited the harvesting of immature cane and relaxed a price freeze on cane. In the final two harvests of the millennium the yield increased, but in the harvests of 2000/01 and 2001/02, the productivity stalled, and only 3.6 million tons and 3.7 million tons were produced, and the industrial yield fell.

In 2002 the restructuring plan Tarea Alvaro Reynoso¹⁶ (Alvaro Reynoso task) was announced. The plan was to increase the efficiency and competitiveness of the sugar industry, to increase food production through diversification and to develop a sustainable agricultural industry supported

¹⁵ Cuba has a dual currency system, as a means to prevent illegal exchange and a dollarisation of the economy. There are goods primarily aimed for tourists that are traded in the convertible peso, and there are goods for Cubans that are traded in the national peso. The exchange rate between the two currencies is approximately 26 national pesos to one convertible. However, many goods can only be acquired with convertible pesos, which are therefore highly desirable.

¹⁶ This was in honour of the well-known 19th-century scientist Alvaro Reynoso, who made seminal contributions to the cultivation of sugarcane.

by strengths in knowledge and human capital. In the plan the ambition was to reduce the sector, concentrate and utilise the best and most productive resources. There was a decrease in the amount of agricultural land dedicated to sugarcane; of a previous 2 million hectares, only 38% would be devoted to this (Mesa-Lago, 2005). The number of mills would be reduced from the nominally operational 156 to 71 (in reality only 110 had been active in 1999/2000 harvest, and the 2000/01 harvest began with 104 mills but ended with only 85) and an additional 14 mills would produce molasses and other by-products. The number of people employed was to be reduced by 50,000 in industry and 50,000 in agriculture. Most mills are located in rural areas, and to avoid social disintegration people were offered generous compensation programmes and a large-scale re-education programme was initiated. Also, the long-standing ambition to reach a sugar output of 7 million was discarded, and the new one was set at 4 million. To reach these goals there was a need to increase the yield in sugar recovery from the cane, by 10–11% to 12%, a figure that Cuba had rarely achieved, only in the 1950s. However, little improvement was reached as the sugar production from the 2002–2003 harvest was 2.2 million tons (the lowest since 1933, when 2 million tons were produced) and 2.5 million tons in 2003–2004 (70% below the level of 1989) (Mesa-Lago, 2005).

In the 2004–2005 harvest there were again severe problems; the beginning of the harvest was delayed one month and lasted only four; only 56 mills operated the full season. There had been severe problems due to a drought that reduced the yield. However, according to an official of MINAZ, this was not the main problem, but rather one of a lack of sugarcane and frequently broken equipment (Mesa-Lago, 2005). Productivity fell from its peak in 1991 with 57.5 tons/ha to 22.4 tons/ha in 2005 (Alonso-Pippo et al., 2008). The result of the harvest was only around 1.6 million tons (the worst since 1905). This caused Fidel Castro to exclaim, “*Sugar belongs to slavery times and will never come back to this country*” (Mesa-Lago, 2005). Once upon a time sugar stood for 35% of GDP, at that time it had shrunk to 5% and in the middle of the 1990s sugar was surpassed by tourism as Cuba’s main industry. As of this time Cuba also began to need to import sugar to meet its internal needs. Furthermore, Cuba has had problems in maintaining quality, which challenges the exportation potential further (A. Torres and Alvarez Delgado, 2007).

As a response to the poor 2006 harvest and the concurrent rising world market prices for sugar, there was a change of strategy, with an aim to triple production in two years. This was to be done by increased investments, increased use of fertilisers and herbicides, increased land use by 120,000 hectares, and the refurbishment and upgrading of 51 mills by importation of replacement parts. There would also be an agreement with foreign investors (Mesa-Lago, 2008). Among other things, there has been importation of 22 combined harvesters (Frank, 2008a). These discussions about joint ventures with foreign firms that began in 2006 had the result that in 2008 there were seven in place, with capital from Spain, Italy, Canada and Mexico, all of which concentrate on the diversification of the sugar industry (Grogg, 2008). Six of these projects were based in Cuba and one in Mexico that markets technological expertise and technical assistance for optimising sustainable sugar production. ALFICSA, a Cuban-Spanish joint venture that produces and sells extra-fine sugarcane spirits, is the only investment in alcohol, which Cuba hopes to develop by modernising 11 of its 17 refineries (Rodriguez, 2007), in 2007 the ambition was to produce 180 million litres annually to use as automotive fuels.

However, the 2007 harvest failed as well, partly due to hurricane problems destroying infrastructure and flooding fields, but also due to industry problems. The target of another 120,000 hectares of land used was not met, and only an additional 30,000 hectares of land were planted; There were delays with four of the 51 mills, but the bigger problem was that the mills frequently broke down, due to a lack of imported supplies and low-quality equipment in harvests. Only 15% of Cuba's provinces and 66% of the mills met their goals (Mesa-Lago, 2008) and the country had to import 200,000 and 250,000 tons of sugar to meet the domestic demand in 2006 and 2007 (Grogg, 2008). In the 2007/2008 harvest the ambition was to improve slightly on the figures from the previous years, by planting 12% more land, using nine more mills and increasing mechanisation. There were problems due to difficulties with land preparation, damaged infrastructure, and the inability of large mills to operate due to late arrivals of harvest machines and replacement equipment. In order to meet the challenges, a campaign of *"100 days of extraordinary effort and victory"* to boost the process was launched (Mesa-Lago, 2008). Despite these problems, the harvest succeeded in producing 24% more sugar than the previous year, 52 mills participated and 28 fulfilled their production plan (Cubaheadlines, 2008a). From the

production Cuba was able to meet domestic demand and export 400 million tons to China and a small proportion to other markets Grogg, 2008).

There were great expectations for the 2008/2009 harvest, as the 2007/2008 one had improved from the year before (Miami Herald, 2008b). There had also been investments in the industry. The sugar refineries had been renovated, remodelled, and working conditions had been improved (Cubaheadlines, 2009). The initial hopes were that the harvest would increase by 25% to 30% (Frank, 2008b). However, a month later Cuba was severely hit by hurricanes, with 156,600 hectares of cane flattened and 518,879 flooded, which caused losses of recovered cane and damage to a large number of mills and factories, railway facilities and warehouses (Frank, 2008c). The 2008/2009 harvest was another failure, due to the hurricane, but also due to a lack of supply of sugarcane as plantations were in poor conditions, challenges with the infrastructure and poor incentives to produce sugarcane (Espinosa, 2010).

In 2009, the Sugar Ministry (MINAZ) had announced that it would restart operations of its sugar by-products plants, beginning with a board factory and a torula yeast factory. These plans had been initiated a few years before, with ideas about the reactivation of production of other derivatives such as processed food, chemicals, pharmaceuticals and biotechnology, animal feed, resins, preservatives, plastics and inputs for pulp and paper mills and furniture factories, but they had been interrupted by the advent of the Special Period and most had not been produced since 1994 (Rodríguez, 2007). These mills could also produce alcohol in different forms. However, this production has been a sensitive topic, not openly talked about, as Fidel Castro expressed negative sentiments about biofuels, asserting that more biofuels would starve the poor. This was a reaction that was sparked by an agreement between Brazil and the United States to promote ethanol production in Latin America and create international quality standards to allow it to be traded as a commodity like oil, and international discussions about ethanol as automotive fuel (Rodríguez, 2007).

Before the 2009/2010 harvest there were modest hopes to improve compared to previous years, but this harvest too was a failure, described as the worst since 1902, when the republic was established. In May 2010, Luis Manuel Ávila González was forced to resign as minister of sugar. He had been appointed in November 2008 and his dismissal occurred just as

Granma revealed that the latest sugar harvest was the worst since 1905 (Leiva, 2010).

Raúl Castro assumed the duties of President of the Council of State in 2006, and was elected president in 2008. Since he took office there has been a slow reform process that targeted agriculture as one of its first areas. In stepwise reforms, more land has been offered to the non-state sector. In 2008 and 2009 1.7 million hectares of unused state land was lent to 82,000 Cubans, in order to reduce the food import which constitutes 60% of Cuban food consumption. Raúl Castro's seems to be more pragmatic and oriented towards a Chinese model.

There has been relaxation of price controls and restrictions on quotas for what needs to be produced by different actors and an opening up of sales of agriculture supplies. Cuba's independent farmers do not think the changes are moving quickly enough, and as a sign of broader change they are urging the government to reduce its control of agriculture, promising that they can increase production volumes and qualities. These petitions were channelled at the 2010 weekend congress of the National Association of Small Farmers, whose 362,440 members – private farmers and members of 3,635 co-operatives – control 41% of Cuba's farmlands but account for 70% of the production. The government has urged agriculture to increase production in order to reduce food imports that in 2008 cost USD 2.5 billion and in 2009 USD 1.8 billion (Nova Gonzalez, 2010). Farmers have accused bureaucracy as the problem and also indirectly urged for better incentives. Farmers have called for better supplies. Furthermore, there was a call for permission to sell directly to markets or to tourism complexes in order to avoid bureaucracy (Tamayo, 2010). Later the government opened up stores selling some of these products, without restrictions and at non-subsidised prices. The ambition is that, within a not too distant future, there will be around 80 products for sale. There are also preparations for reforms to drop the contracting system, forcing farmers to interact with state farms and mills regarding what to grow (Frank, 2010a). Raúl Castro has also opened up discussion about increased possibilities for self-employment, co-operatives in new industries, and removing some of the legislation prohibiting employment in private firms, which prevents the growth of firms and innovation (Frank, 2010b). In September 2010 the official trade union announced that 1 million state employees would be made redundant and that 500,000 employees will be laid off by April 1, 2011 (Mesa-Lago, 2010).

This is the biggest shift in employment between private and public sector since the 1960s. In November 2010 the Communist Party has also published a document to stimulate discussions on how to change the Cuban economy with ideas of more decentralized decision making for firms and policymakers, insolvent firms will face liquidation, studies on how to merge Cuba's two currencies. Declarations of need to augment sugar production for exportation, implement mechanism that better diffuse internationally favourable sugar prices to sugarcane producers; to increase the production of derivatives, prioritizing alcohol, food production, animal feed (PCC, 2010).

4.6 Cuban Institutional Set-up

When describing the sugar clusters in Cuba, one could see the entire island from a meta-perspective as a large industrial cluster consisting of many overlapping small regional clusters which have at the centre a sugar mill, and once could also analyse these smaller clusters. During the 1970s many mills and surrounding lands were changed into agro-industrial complexes, and the sugar mill still dominates the surrounding rural areas. Sugar exists in all areas of the country and there are refineries spread all over the island. Before the restructuring in 2002, the 156 mills that existed were located in 100 of Cuba's 169 municipalities. Sugarcane was the dominant activity in another 25 municipalities. The mills were so important that cities or towns grew around them, and in 29 of such municipalities the mills became the seat of municipal government. In the restructuring campaign 85 mills were to remain for production of sugar and molasses, with a total daily grinding capacity of 401,700 metric tons, which corresponded to 62.1% of the prior overall sugarcane grinding capacity (Alvarez Lopez and Perez, 2006). Nevertheless only around 50 mills have been utilised in the latest harvests (Mesa-Lago, 2008; Cubaheadlines, 2008a; Espinosa, 2010). In the restructuring plan all provinces were affected, but mostly the central provinces, as these were the ones that had the highest number of small units. After the restructuring the centre of gravity in the sugar industry moved further east. Before the reforms the centre was Villa Clara, followed by Camagüey and Matanzas. After the reforms Ciego de Avila is most important with 6 mills with a milling capacity of 53,000 metric tons of sugar per day, followed by Camagüey with 7 mills with a capacity of 42,300 metric tons of sugar per day and 2 mills with a capacity of 12,600 tons of

molasses per day; then comes Villa Clara with 11 mills with a capacity of 35,800 tons of sugar per day, and 2 mills for molasses and a grinding capacity of 6,500 tons per day (Alvarez and Perez-Lopez, 2006). The location of the regions is shown in Figure 6.

Figure 6: Map of Cuba



Source: Claudio (1999)

Of the remaining Cuban mills, 16 have annexed ethanol distilleries with the capacity to produce hydrated ethanol, mainly for rum, other beverages and technical alcohol (Alonso-Pippo et al., 2008).

If Porter's definition is taken literally, with a geographical concentration of a critical mass of firms and organisations in a related economic activity, there is no major contradiction between what exists in Cuba and the Porter model. However, the set-up of the Cuban clusters is very different, in particular with regard to institutional arrangements and institutional set-ups. Actors and activities are very much more co-ordinated and planned than what is presumed in Porter-type clusters, and the associated outcomes for innovation. Competition is restricted, possibilities for specialisation and firm start-up and decisions on whom to collaborate with are restricted and decided top-down. Clusters more resemble conglomerates or what Markusen referred to as State-anchored districts, where an agglomeration is centred around a public activity that dominates and influences surrounding actors. Still, as we will see below, in the clusters of the planned Cuban economy there is a mix of institutional arrangements, even though the state is very dominant.

All the Cuban mills are owned by the Sugar Ministry, MINAZ and the same goes for the purchasing board (Acopio), which is the centre for purchasing agricultural products. MINAZ also controls the firms handling exportation, while Technoazucar sells the derivatives and Cuba Azucar sells the sugar. Sugar is also the basis for around 150 subcategories of goods and services, such as commercialisation of services (e.g. export of sugar engineers to Venezuela), glue, chemical products, technology, electricity, animal feed, etc. (Fernandez Dominguez, 2006).

At the centre of the regional clusters are the refineries that control many of the surrounding actors and can be seen as agro-industrial complexes. Most complexes do not only control the surrounding areas, but also have a responsibility to provide employment and to produce food for the region therefore many of them produce other agricultural products beyond sugar-related crops – a task that increased after the land reform, as MINAZ kept control over the land previously used for sugar production that was altered for forestry, aquaculture and food production. There have also been ambitions with the restructuring of the sugar industry to recuperate rain forests, and biodiversity, as well as to strengthen communities of indigenous peoples (Sao Pensa, 2007). The official rationale is that MINAZ should take responsibility for the unemployed from the restructuring of the sugar sector.

Mills can also incorporate transportation and harvesting services, which are provided to the neighbouring production units (Fernandez Dominguez, 2006). Cuba is highly mechanised even if the usage is falling, and in 2008 the harvest was managed to the tune of 87% by mechanised harvesters (El Nuevo Herald, 2008).

Being an island, there are never any great distances to transport products to a harbour and export. There are railway and roads that can transport relatively easy from the inland and to the coast and railways that are specifically used to transport sugarcane from the fields to the refineries, as in the Hector Molina refinery which was visited during the project. The infrastructure is worn out though and there is work going on to upgrade railway system (Fernandez Dominguez, 2006).

The sugarcane is produced mainly by the non-state sector, see table 10. This is something that changed with the Special Period; before this around 66% of cane was produced by the state sector, afterwards very little. The non-state sector consists of small private farmers and four types of co-operatives.

The most efficient ones are the private small producers, who are organised in the ANAP (Asociación Nacional Agropecuaria), then in decreasing order (Fernandez Dominguez, 2006; Nova Gonzalez, 2006) come the 2,000 credit co-operatives (CCS), which own their land and co-operate to purchase goods or take loans, they can keep 75–80% of their profits, but are obliged to pay a percentage to a common fund to pay for accountants and sales staff. Then there are around 100 Instituciones Naturales, special co-operatives where the farmers rent their land privately, but have some limited collaboration with other farmers (this form is mainly used in coffee and tobacco). Then there are around 1,000 CPAs, co-operatives that are jointly owned by the farmers and the co-operative owns the land. There are approximately 1,600 UBPCs that do not own their land but lease it from the government. These were created after the Special Period when state farms were turned into co-operatives. These have great problems with efficiency, as 60% run a deficit. They have experimented with letting parts of the land be farmed individually, and in these areas productivity has risen substantially. Individual farmers have achieved yields of 100 tons of cane/ha and higher, which is substantially higher than the yields of co-operatives (Alonso-Pippo et al., 2008). At the same time, the efficiency problems of UBPCs are troublesome as they handle around 75% of the land dedicated to sugarcane, while CPAs and CCSs have an additional 15%, and the remaining 10% is managed by the other units (Alvarez, 2005).

Table 10: Harvested area, production and yield of the sugarcane destined to the sugar industry, per harvest season in Cuba

Harvest Year	Grown area (Mha)			Production (MMT)			Productivity (T/Ha)		
	Total	State	Non-State	Total	State	Non-State	Total	State	Non-State
1983/1984	1,349.5	1,102.8	246.7	77.4	63.2	14.2	57.4	57.3	57.6
1989/1990	1,420.3	1,192.0	228.3	81.8	67.0	14.8	57.6	56.2	64.8
1994/1995	1,177.4	60.1	1,117.3	33.6	1.7	31.9	28.5	28.3	25.8
1999/2000	1,040.9	89.7	951.2	36.4	2.9	33.5	35.6	32.2	35.9
2004/2005	517.2	21.8	495.4	11.6	0.4	11.2	22.4	18.3	22.6
2007/2008	380.3	10.5	369.8	15.7	0.4	15.3	41.3	34.9	41.4

Source: ONE (2008a)

The strategic decisions of most of these units, their salary levels and prices are controlled by the ministries and the sugar mills. There are currently

changes going on and there are discussions on letting UBPCs take over their land, and also allowing for more private farming. Currently the UBPCs are dependent on the Union of Enterprise Operators of Sugar and their Derivatives (UESD), a part of the Ministry of Sugar. The UESD sets up quotas for how much cane each co-operative should produce, land distribution, what prices producers shall receive, etc. UESD has also managed the stores of agricultural supplies, such as tools, machinery, fuels, meat, clothes, etc. This has been traded in convertible pesos, but the farmers have been paid in national pesos, creating great disincentives for producing agricultural goods (Alonso-Pippo et al., 2008).

In the last few years a number of measures to decentralise agricultural production have been carried out. There is more land available for individual farming and there is the beginning of a removal of restrictions on what to grow, and preparations are in progress to remove the purchasing boards. There is also an easing of restrictions in the supply stores, and some goods are sold in free quantities and at market prices (Frank, 2010a). However, whether these are temporary changes in order to meet an economic crisis or are of a more permanent order remains to be seen. For example, in 1993 the government legalised self-employment in a number of retail activities, but later reduced the number of licenses available as the economy was strengthened.

There are a further 300 firms, mainly different intermediaries and some co-operatives, and firms for transportation and construction (Fernandez Dominguez, 2006). These firms do not distribute their profits, as there are incentive schemes in place in order to try to raise productivity.

Then there are the seven joint ventures with foreign firms with capital from Spain, Italy, Canada and Mexico, all of which concentrate on the diversification of the sugar industry. Six are based in Cuba and one in Mexico, where it markets technological expertise and technical assistance for optimising sustainable sugar production (Grogg, 2008).

Cuba has a strong scientific and technology capacity, and there are four notable R&D institutes for the sugar industry, apart from research and education within the universities. There is the National Institute for Sugar Investigations (INICA, Instituto Nacional de Investigaciones de la Caña de Azúcar) – agricultural development that focuses on agricultural processes. It deals primarily with technology transfer, innovation, training and

dissemination of knowledge. The Cuban Institute for Sugar Investigations (ICINAZ, Instituto Cubano de Investigaciones Azucareras) addresses industrial processes, promotes the development of new technology, and adopts technology from other countries, to be fitted into processes in sugar mills. They do feasibility studies, building capabilities through education, they give technical assistance both domestically and internationally, they develop boilers and co-generation systems to increase the use of harvest waste and develop software for management processes. Then there is the Cuban Institute for Investigations of Sugarcane Derivates (ICIDCA, Instituto Cuba de Investigaciones de los Derivados de la Caña de Azúcar), which focuses on derivates that come after the industrial processes, such as food products, biotechnology, polymer technology, medical technology, computing models and techno-economics. Finally there is Cuba 9, an experimental centre (Nova, 2007a).

The Cuban sugar industry is in decline, and large shares of the land are abandoned, even though there has been a programme to allow private farmers take over and use it. In 2008, just before these reforms, estimations indicated that 50–60% of previous sugarcane land was simply unused and large parts have started to become overgrown with Marabú trees, with very complex root systems which are very hard to remove (Mesa-Lago, 2008).

The sugar industry has shrunk in importance, now representing around 10% of export earnings, while services passed sugar in the mid 1990s. At present tourism stands for around 30% of earnings and other services for around 30–40%. These other services are mainly teachers and doctors active in Venezuela (Pollitt, 2008). Furthermore, vaccines generate around 10% of export earnings. Even though sugar has fallen in importance, it is still a major industry for the Cuban economy.

4.7 Innovation Outcomes in Cases

In this section there will first be a presentation and a comparison of extensive data, for the different cases and time periods: i) innovation surveys; ii) patents as an indication of innovation (even though it does not say anything about the commercial value or to what extent this has been put to use); iii) types of patents awarded, as an indication of what types of innovation is generated; iv) scientific articles, both to explore knowledge

production and as an indication of knowledge capacity; vi) productivity and production measures in the form of sugarcane, sugar and ethanol output, to provide an indication of long-term innovativeness, based on the argument that in order for firms to stay long-term competitive they need to be innovative, and that it is innovation that raises productivity and production outcomes. It is also a way to capture innovations that may not be filed as patents or described in scientific articles. This is followed by a presentation of qualitative indications in the data material, sorting data along lines of different innovation categories. At the end there is a summary of the findings and picture description of the innovation outcomes, types of innovations and innovativeness of the different cases.

4.7.1 Innovation Surveys

4.7.1.1 Brazil

The Brazilian Institute of Geography and Statistics (IBGE) has carried out four surveys of Innovation in the Brazilian Economy called Pintec (in 1998–2000; 2001–2003; 2003–2005; and 2006–2008). The studies are based on the third edition of the OECD Oslo manual of innovation indicators and are compatible with international surveys like the EU Community Innovation Survey (CIS). The surveys include firms that have met the following requirements: i) being registered as active in the relevant categories with the Central Register of Enterprises – CEMPRE of IBGE; ii) being based in any part of the national territory; and iii) having ten or more employees. The response rate was around 25% of the total sample.

For the purpose of this thesis it has been particularly interesting to use data in the following categories: fabrication of coke and biocombustibles (ethanol and others), which I will use as an indicator of the mills' innovation activities, even though the sample contains other activities than purely ethanol, and there is not mills that are only producing sugar; fabrication of machinery and equipment, which I will use as an indication of suppliers of process equipment, even though it incorporates all types of machinery and equipment in Brazil; the data can be separated for all São Paulo firms and for all Pernambuco firms, which I will use as indicators of regional differences.

Table 11: Innovating firms in ethanol and coke industry and equipment and machinery

	2000	2008	Growth rate
Ethanol and coke industry	149	204	37%
Firms innovating % of all	32%	46%	44%
Category's % of total value created by all innovations	0.8%	1.2%	50%
Equipment and machinery	3924	5551	41%
Firms innovating % of all	44.5%	51%	14%
Category's % of total value created by all innovations	5.1%	5%	-2%

Source: IBGE (2002, 2010)

The ethanol industry has grown in the period from 149 firms to 204, representing a growth rate of 37%, of the firms innovating there has been an increase of 32% to 46% a growth rate of 44%. However, there is not only a growth in size, but the relative economic importance of the innovations has also increased and the value of the ethanol industry's innovations out of all Brazilian innovations has increased from 0.8% to 1.2%, see Table 11.

For the machinery and equipment industry the growth rate of the industry has been 41% and the growth rate of firms innovating has increased from 44.5% to 51%. At the same time as there has been an absolute growth of the sector and its innovation, the relative importance has fallen slightly, from 5.1% of total value of innovations to 5%.

The Ethanol Industry

In the ethanol industry 46% of all firms innovate; they are mainly carrying out process innovations, 46%, which are new to the firm, 40%. There is a slight increase in innovations that are new to the market, 7% from 0.7%. There are also some product innovations, 18.3%, and these are mainly new to the firm, 17.8%. There has been growth in both categories of innovations, see Table 12.

In 2000 the main activities for innovation, as indicated by the firms that were innovating, were the acquisition of software and machinery and equipment and different types of market research activities, 79%, 73.5% and 60%. In 2008 it seems that the role of human capital had increased with more importance for training, market research and internal R&D, but

the acquisition of equipment was still the most important along with software. This can explain the high numbers for process innovations that are new to the firm for the ethanol industry.

Table 12: Ethanol industry

	2000	2008
Total number of firms innovating	32%	46%
Product innovation	13.5%	18.3%
– New to firm	13.5%	17.8%
– New to national market	0	0.5%
Process innovation	30%	46%
– New to firm	30%	40%
– New to national market	0.7%	7%

Source: IBGE (2002, 2010)

Note: Figures are percentages of all firms in the category, not percentages of firms that are innovating.

Regarding the sources of innovation, it is interesting to observe the relatively low importance of the firms' own R&D units, whereas both external sources such as customers, suppliers and information networks are highly important, and the internal non-R&D sources. Sources indicated as being of high relevance for innovation by the firms were in 2008: customers 62%, information networks 53%, suppliers 31%; internal non-R&D sources 54% (internal R&D was only 7%) and consultants 19%, test and certification institutes 19% and universities 10%.

Machinery and Equipment Industry

There seem to be more innovations coming out of the machinery and equipment industry than the ethanol industry, and also more product innovations and innovations that are new to the market, whereas the ethanol industry has more process innovations. This may reflect that the machinery and equipment industry is supplying to the ethanol industry, and supplying it with products, whereas more efforts in the ethanol industry lie in improving processes and the output portfolio is more fixed.

In this category 51% of all firms were innovating in 2008, carrying out both product (32.1%) and process innovations (46%). Process innovations grew from 28.2% in 2000 to 38.3% in 2008; whereas product innovations fell

slightly from 33.5% to 32.1%. Innovations are mainly new to the firm, but there are some product innovations that are new to the market, 10.1%, though this has fallen in relative values from 14.5%, see Table 13.

Table 13: Type of innovation in machinery and equipment industry

	2000	2008
Total amount of firms innovating	44.5%	51%
Product innovation	33.5%	32.1%
– New to firm	21.2%	24.4%
– New to national market	14.5%	10.1%
Process innovation	28.2%	38.3%
– New to firm	24.7%	3.7.2%
– New to national market	4.4%	1.5%

Source: IBGE (2002, 2010)

Note: Figures are percentages of all firms in the category, not percentages of firms that are innovating.

When it comes to activities among innovating firms, purchasing of machinery and software is less accentuated than for the ethanol industry, but it is still important. In 2000 internal R&D was much more important in machinery and equipment (42%) than for the ethanol industry (4.5%), but for 2008 it had altered to 12% and 21.5%. In 2008 the most important activities were buying machinery 58% and software 32%, training 36%.

Among firms that were innovating in 2008, highly relevant sources were information networks 54%, internal sources non-R&D 48% (internal R&D 12%), customers 46%, trade shows 40% and suppliers 33%.

São Paulo and North East

These data cover all firms included in the survey from São Paulo and Pernambuco, regardless of industry, but can explain some differences between the two regions. São Paulo is a very important state, and the value of the innovations originating from the state represents 43% of all innovations in Brazil, while the same figure for Pernambuco is 0.9%. At the same time there is not a great difference in the rate of firms innovating.

In São Paulo 36.5% of firms in the sample innovate, which is an increase from 32.6% in 2000. There is slightly more process innovations, 29.5%, than product innovations, 23.2%. However, there are more product innovations that are new to the market than process innovations, 6% and 2.5% respectively. There has been a slight decrease in the relative numbers of innovations new to the market, from 6.1% to 6% of product innovations and from 3.5% to 2.5% for process innovation, see Table 14.

Table 14: Type of innovation in São Paulo and Pernambuco/North East

	São Paulo		Pernambuco/Northeast	
	2000	2008	2000*	2008
Total amount of firms innovating	32.6%	36.5%	31.2%	31.6%
Product innovation	19.3%	23.2%	14.9%	15.8%
– New to firm	14.7%	18.7%	13.8%	15.2%
– New to national market	6.1%	6%	1.7%	0.6%
Process innovation	25%	29.5%	26.7%	23.9%
– New to firm	22.5%	28.5%	24.6%	23.5%
– New to national market	3.5%	2.5%	2.4%	0.7%

Source: IBGE (2002, 2010)

Note: Figures are percentages of all firms in the category, not percentages of firms that are innovating.

*Data for 2000 are for the North East and not only Pernambuco.

The relative numbers of total firms innovating for Pernambuco is not so far away from the figure for São Paulo, even though it seems as if the growth of total number of firms innovating is not rising as rapidly. The numbers are also lower for product and process innovations. São Paulo is also generating more innovations that are new to the market than Pernambuco. In Pernambuco process innovations are more important than product innovations. There is also a decrease in process innovations and also in innovations that are new to the market, of both categories. However, there is a danger that the differences in samples in the 2008 numbers are for the state of Pernambuco, whereas the 2000 numbers are for the entire North East may explain part of these differences.

With regard to innovation activities, the most important ones in São Paulo were acquisitions of machinery and equipment 54.8%, market activities 21.6% and it is notable that internal R&D is 3.6%. Likewise in Pernambuco internal R&D is only considered by 3.1% as an important activity. The important activities in Pernambuco were acquisitions of machinery and equipment 52.6%, training 45.5% and acquisition of software 18.5%.

When it comes to sources indicated as being of high relevance for innovation by São Paulo firms that were innovating in 2008, the most important were information networks 47%, customers, 46.4%, then internal sources non-R&D 41.7% (internal R&D 10.6%) and suppliers 39.9%. The categories of source are similar for São Paulo and Pernambuco with regard to innovation sources, but in Pernambuco the role of internal sources for innovation is notably lower; other internal sources are at 19.4% and internal R&D is at 2%.

Of innovating firms, 11.7% in São Paulo consider collaboration important, and 5% in Pernambuco. The partners considered most important for innovating firms in São Paulo were suppliers 6.7% and customers 4.5%. In Pernambuco it was suppliers 2.7% and consultants 2.6%.

Generally speaking, for the categories explored here it is most commonly process innovations that are new to the firm, and also the main activity for innovation is acquisition of machinery and equipment and software and to some extent training. Internal R&D is relatively unimportant; the exception is the ethanol industry in 2008, where it was considered to be important by 21.6% of innovators. However, the category of internal sources non-R&D has been important in all cases. Other important sources are suppliers and consultants. Relatively few consider direct co-operation as important for innovation, but the more important partners are suppliers, customers and consultants; this implies that user-producer learning is important, but that joint action with research units is considered of lesser importance by respondents in the Pintec survey. São Paulo generates more innovations, collaborates slightly more and uses internal R&D more. The machinery and equipment industry generates more innovations than the ethanol industry, more product innovations and more innovations that are new to the market. However, the trend for ethanol is growing numbers of innovations and more efforts in R&D.

4.7.1.2 Cuban Data

The Cuban National Statistics Office (ONE) has also gathered data on innovation and rationalisations in the Cuban economy. The data are structured for provinces, syndicates and organisms, as well as the remuneration paid to innovators. What is described below for the sugar industry concerns innovations and rationalisations by people registered in the sugar industry union, while the other category is for people employed by units belonging to the Sugar Ministry, MINAZ.

Innovations are technical solutions that are new and useful, providing a technical, economic and social benefit and constituting a change in design or production technology of an article or the material composition of the product. Rationalisation is a solution to a technical or organisational problem, which is implemented and provides a technical, economic or social benefit. There is a category called applied innovations and rationalisations that contain the number of innovations and rationalisations that were implemented during the reporting year. The statistics office has presented data for three years, 2005, 2007 and 2009.

However, the data are not consistent with international standards and it is somewhat hard to compare with other countries. When reviewing the data there can be sharp fluctuations between years, indicating either that the survey categories are not clear to respondents, or that there have been radical shifts. Here I intend to use the data to analyse the role of innovation in the sugar sector, compared to other sectors and development over time. However, the data do not give any indications of collaboration or sources of innovation, or where in the economy they are taking place. There is no indication of the degree of product or process innovations, or whether they are innovations or rationalisations, which could indicate the degree of innovativeness. In the Cuban case what can be observed is that innovations and rationalisations are taking place and that they generate important value to the economy, see Table 15.

The value generated by innovations by persons who are members of the sugar industry in 2009 was as large as 0.047% of the GDP. The value of innovations increased from 2005 and 2007, and also represented a value amounting to 12.3% of the value of all innovations in Cuba. At the same time the number of innovations has fallen to around a third of what it used to be. The same pattern is indicated by the figures for people registered with

the Sugar Ministry, MINAZ (of which a large part are also registered with the sugar industry syndicate).

Table 15: Cuban innovation

	2005	2007	2009***
Sugar industry			
Innovations applied *	1512	1584	552
As % of all innovations	4%	6.4%	3.0%
% of economic value of all innovations	7.4%	5.3%	12.3%
% of GDP	0.038%	0.018%	0.047%
MINAZ			
Innovations applied**	1788	1766	696
As % of all innovations	4.8%	7.2%	3.8%
% of economic value of all innovations	8.7%	6.9%	14.3%
% of GDP.	0.045%	0.023%	0.055%
The sugar industries production as % of GDP	5%	3.3%	3.8%

Source: ONE (2005), ONE (2008c), ONE (2010)

Note:* Applied innovation or rationalisation, in number per union, in this case the sugar industry union. ** Within the organisations belonging to the Sugar Ministry; *** for % of GDP, for 2009 GDP 2008 were used, as no 2009 data were available.

What one can also see is that the innovations coming out of the sugar sector are relatively more important for the Cuban economy, than for the Brazilian one. The value of innovations in Brazil from ethanol was 1.2% of the value of all innovations, and for all equipment and machinery industry it was 5%, whereas the value of innovations in Cuba was 12.3% for sugar industry and 14.3% for MINAZ.

4.7.2 Patents

For the patent analysis, data from the Free Patents Online database were used. Included in the data set were patents from WIPO, US-approved patents and EU patent data. A number of search strings were used in order to make the data relevant to the clusters. There was a search for patents separated by looking for country of origin of patent holders. Cuba was

treated as one cluster. The Brazilian data were separated into the North East and São Paulo.¹⁷

The point of departure was a search for patents filed in the main category of sugar production of the international classification system called class C13. This, however, did not capture all patents relevant in the cluster; for example, it was missing out patents relevant for ethanol diversification. After this the search was broadened to include patents that had sugar in the abstract, to allow for more diversification and innovation to be observed. To open the search even more, the search string was widened to look for all patents with sugar in the text. The problem with opening up the search string wider is that clearly irrelevant patents are also included, such as a patent for a Colibri bird feeder. To further explore the patents to acquire a better picture, there was a search for Ethanol and Alcohol in the abstract of the patent and anywhere in the text. However, there are complications with this, as patents with sugar and ethanol/alcohol in them capture other types of patents that relate more widely to chemical processes than to the sugar industry. However, by searching with these different strings and allowing for stricter and freer searches concerning sugar, a more complete picture was created. The searches show more or less the same picture of the cases, regarding the development over time, as well as the relative amount of patents produced in the regions. The best match was with the search made for Sugar Cane and Sugarcane anywhere in the text and these were the data that I choose to work with. This is the best filter for capturing relevant patents at the same time it reflects the general development for the cases in development over time of patents, as illustrated in Table 16.

When exploring patent data, it can be observed that the state of São Paulo has a very large share of all patents in all categories in the Brazilian context, and that Piracicaba, for its size, is a major producer of patents related to the sugar industry. Other important locations for patents in the state are the city of São Paulo, the university town of Campinas, Ribeirão Preto and Lorena. Furthermore, from the 1970s onwards there has been an exponential growth of patents in the state of São Paulo. In Piracicaba, though, there were some

¹⁷ For more information see section 3.5.2

patents in the 1970–1990 period, but very few patents in 1990–2000. The pattern of Piracicaba can be interpreted by changes due to the closure of Proálcool. Dedini, which produces a large share of the patents in Piracicaba, filed a number of patents in the 1980s, but had a decline when Pró-Álcool was closed down in the early 1990s, but picked up again in the early 2000s (Tosi et al., 2008), when there was a renewed growth in the market. From 2001 onwards there has been a great surge in patents in Brazil, São Paulo and Piracicaba. When comparing the different categories it can also be observed that Piracicaba has fewer patents with references to alcohol and ethanol than other patents, and compared to the other geographical areas, whereas the North East only has notable numbers of patents in this category. However, these patents in the North East, when individually explored, have relatively little to do with the sugar industry and more with the medical and chemical industries.

Table 16: Patents in the different cases compared over time

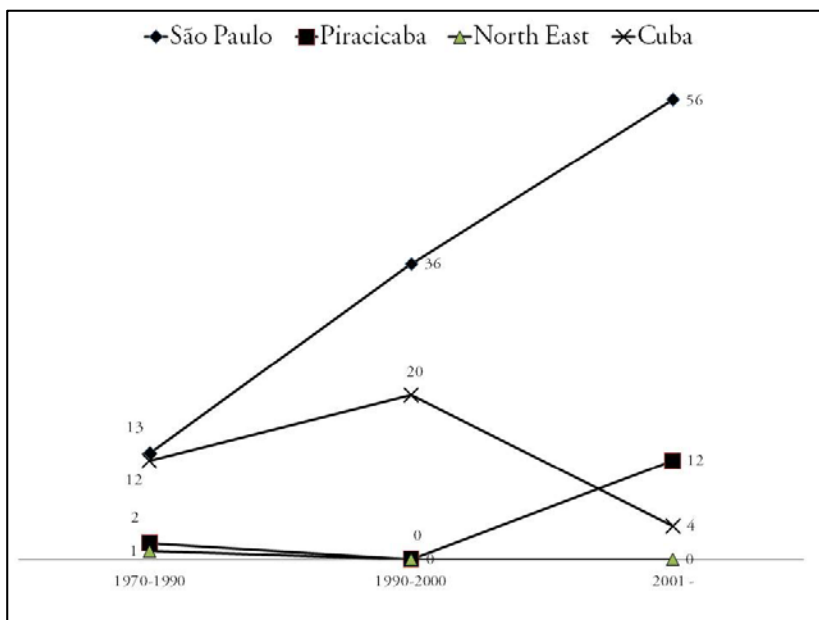
	Brazil	São Paulo	Piracicaba	North East	Cuba*
All: Class 13	44	20	4	0	4
1970–1990	4	3	0	0	3
1990–2001	11	5	0	0	0
2001 –	29	15	4	0	1
ABST: Sugar Cane or Sugarcane	44	19	5	0	15
1970–1990	7	7	2	0	2
1990–2000	2	1	0	0	12
2001–	35	11	3	0	1
All: Sugar Cane or Sugarcane	261	105	14	1	36
1970–1990	20	13	2	1	12
1990–2000	67	36	0	0	20
2001–	174	56	12	0	4
All: Ethanol/Alcohol	1684	496	18	10	122
1970–1990	94	21	1	1	21
1990–2000	372	129	1	3	51
2001–	1218	346	16	6	50

Source: Free Patents Online

Note: * Cuba's timeline is from 1970–1993 and 1993–2001. ** Populations in millions are: Brazil (190), São Paulo (41), Piracicaba (0.35), Pernambuco (8) and Alagoas (3) and Cuba (11)

The North East has few patents. The one with strict connection to the sugar industry is a patent from 1980 for an “*Individual Bagasse Drier*”, which decreases the moisture of the bagasse, by an inventor from Maceio in Alagoas, and there is an application for a patent from 2008 for “*industrial methods involving the hydrolysis of sugar bagasse*” from Pernambuco. Still there are so few patents that it is hard to draw any far-reaching conclusions about trends or compositions from the data, other than that the technology capacity is substantially lower in the North East than in the other cases.

Figure 7: Patents of sugar cane per case over time 1970–2010



Source: Free Patents Online

Cuba had patents related to the sugar industry before Brazil did, and the growth in 1970–1993 was not far from that for the state of São Paulo in 1970–1990, with only 25% of the population. Despite the crisis of the Special Period, Cuba continued to increase patents in most categories (except for Class 13); in our categories they managed to produce more in almost only a third of the time period, 1970–1993 and 1993–2001. Since 2001, however, patents have plunged in Cuba in all categories, except for

ethanol and alcohol, where it produced almost as many in 2001–2010 as in 1993–2001. This also reflects an important change in trends of the Cuban patents, with a move towards biotech patents, and with connections more to medicine than to the sugar industry itself. The themes of patents with sugar are along the lines of “*Mixture of higher primary aliphatic alcohols, its obtention from sugar cane wax and its pharmaceutical uses.*”

The trend of patenting in all the cases is illustrated in Figure 7; the background data are based on the search category where Sugarcane or Sugar Cane is mentioned anywhere in the patent, which is the category that best represents the overall development of all the categories searched. São Paulo and Piracicaba is growing, whereas Cuba is falling and in the North East little is happening.

Innovation Types

In order to analyse what kinds of innovations are generated in the different clusters, the sugarcane patents have also been divided into categories of process or product innovations. Patents approved for a method or a process were classified as a process innovation, whereas patents for apparatus, products, machines, devices and mixtures and similar descriptions were classified as product innovations. There were no indications of market or organisational innovations among the patents.

In the first period analysed, 1970–1990 for Brazil and 1970–1993 for Cuba, product patents dominated in São Paulo and Cuba, whereas for Piracicaba it was 1:1, see Table 17. The North East’s patent is a product patent, but the North East will not be analysed in the absence of data.

Table 17: Types of sugarcane patents until 1990 for Brazil and 1993 for Cuba

	São Paulo	Piracicaba	Cuba
Process patents	4	1	2
Product patents	9	1	10

Source: Free Patents Online

However, from 1990 onwards, there is a shift in São Paulo, as process innovations have become more important. There are no patents from Piracicaba or the North East in this period. This is not the case in Cuba, where product innovations remain more important, see Table 18.

Table 18: Types of sugarcane patents 1990–2000 for Brazil, 1993–2000 for Cuba

	São Paulo	Piracicaba	Cuba
Process patents	28	0	0
Product patents	8	0	20

Source: Free Patents Online

The relation is the same in the next period, where process patents clearly dominate product patents in Brazil and in Cuba it is the other way around, see Table 19.

Table 19: Types of sugarcane patents 2000–2010 for Brazil and Cuba

	São Paulo	Piracicaba	Cuba
Process patents	40	9	1
Product patents	16	3	3

Source: Free Patents Online

A suitable system to classify patents in groups of radical or incremental innovations could not be developed, since estimating the potential outcome of the patents is beyond the scope of this thesis and the techno-economic knowledge of the author. However, a reading of the patent descriptions reveals few that immediately indicate radical innovations, neither in Brazil nor in Cuba. The greatest potential is probably related to the rapid hydrolysis from Dedini in Piracicaba. There is also a patent application from the firm Bioenzymes in Pernambuco regarding enzymes for hydrolysis. If this is successfully developed beyond pilot to commercial scale, the technology could enable the next generation of biofuels. There are estimations that this type of process could increase efficiency in ethanol production from sugarcane by 50% (Jagger, 2009), which would radically alter the possibilities for broad based use of ethanol from sugarcane.

4.7.3 Scientific Articles

In the search for the numbers of articles published, the database of Web of Science with Conference Proceedings (ISI) was used. I have searched for articles on the topic of sugarcane and explored the total number of articles in different periods to see the evolution over time, and I have also filtered the

articles depending upon whether they have been cited or not, as an indication of quality. Cuban articles have been searched with Cuba in the address field; for Brazil the search was with Brazil in the address field, and then for the category of Piracicaba, which was an additional address field, and for São Paulo I used São Paulo or SP in the search fields and for the North East I used Pernambuco or PE or Alagoas or AL. In Table 20 the number of articles from the different locations are presented and also in which sub-categories they are most commonly published.

The patterns from the analysis of patent data are also reflected in the scientific articles that Brazilian capacity was lagging behind Cuba before the 1970s, but now total production is greater; in the case of scientific articles the number of Cuban articles is still growing, though, and has not fallen as patents have.

Just as Cuba was ahead of Brazil in patents, Cuba had more articles published than Brazil up to the 1970s. As the time period for Cuba is from 1971–1993 and 1994–2001 they have more articles than Brazil in this period, but the articles published from 1971–1990 was 49, so in this era Brazil overtook Cuba. However, Cuba keeps on publishing despite the Special Period and problems in the industry, and the rate of growth is decreasing. As with the development of subjects of patents, pharmacology is growing in importance, but agriculture and plant science are keeping up their levels of importance.

When exploring the addresses of the authors of the scientific articles, one can see that Havana notably dominates the addresses, with 468 papers, while the second most common place is Matanzas with 21 papers, then Santiago with 11, and Villa Clara with 10. So even though there have been efforts to avoid concentration of productive capacities in certain regions and also recent efforts to universalise higher education, this has not been followed by the capacity to produce scientific articles, which is dominated by Havana.

Even though Cuba is not increasing the number of articles published as quickly as Brazil, if one makes a per capita comparison for production in the last decade, Cuba and São Paulo are quite similar, as São Paulo has four times as large a population, and there are approximately four times as many cited articles with an author related to São Paulo. The output is also three and a half times as much as for the North East, which is equal in population size. However, persons with relation to Piracicaba have published as many

cited articles as from Cuba, even though the total number of published articles is slightly lower.

Up to 1970 there were no articles published from Brazil, which implies that the research capacity was lower at that time, but also that researchers found it less important to publish in the journals that are part of the index. From 1970 onwards it has grown slowly, and has done so in an exponential rate for all of Brazil and the cases, except for North East where the growth pattern is more linear, but steadily increasing. Piracicaba is represented high in the statistics, and São Paulo is a major contributor to all of Brazil's articles.

Table 20: Number of scientific articles on the topic of sugarcane cited at least by one and total number.

Time	Brazil	São Paulo	Piracicaba	North East	Cuba*
All	1537 (2377)	980 (1468)	233 (345)	73 (137)	370 (557)
Pre70	–	–	–	–	2 (4)
1971–1990	56 (101)	38 (65)	13 (20)	6 (8)	64 (84)
1991–2000	355 (458)	212 (267)	41 (49)	16 (28)	125 (175)
2001–	1226 (1818)	730 (1136)	179 (276)	51 (101)	179 (294)

Source: Web of Science with Conference Proceedings (ISI). Accessed November 16, 2010.
Note: * Cuba's timeline is before and after 1993.

From 1970 to 1990, 23% of the cited articles on sugar were from Piracicaba and 68% from São Paulo. During the 1990s Piracicaba and São Paulo produced relatively less, 11% and 60%. Still in absolute numbers the articles increased radically; the number of articles from São Paulo grew by 558% and from Piracicaba by 315% (even though the period is twice as long in the first case). In the period there is also a rise in topics related to plant science and biotechnology.

Then from 2001 onwards the relative importance of São Paulo and Piracicaba grew again to 60% and 14% respectively, and the number of articles in absolute numbers continued to grow, with an increase of 345% in São Paulo and 437% in Piracicaba. The area of interest in Piracicaba was agriculture and plant science and for the state of São Paulo it was

biotechnology. This may be because ESALQ is mainly an agricultural university. Other strong locations in São Paulo state are the cities of Campinas, with 332 articles in total over the years published (not separated for cited ones), São Carlos with 205 and Ribeirão Preto with 73.

In the North East there were no articles before the 1970s and in the period 1970–1990 very few cited articles were produced with relation to sugarcane, actually only six of them and eight published ones. However, in the next decade there was a growth to 16 articles, even though there was an absolute growth, the relative production in comparison to Brazil in general fell. The articles have been mainly on agronomy and agriculture. This could reflect that there more natural production and processing plants, but not an equipment industry and research for this industry in the North East. From 2001 and during the following decade, 51 cited articles and 101 in total were published, and the relative percentage in the Brazilian production rose, with microbiology as a growing topic. The production of articles reflects that there is much less science and technology capacity in the North East region compared to Cuba, São Paulo and Piracicaba, and less knowledge output, but it is growing. The other locations are very strong producers of articles, particularly Piracicaba.

4.7.4 Long-term Innovativeness

There are challenges to find monetary indicators of the sugar industry that are comparable between the three cases, and so I have chosen to compare output in the production of sugarcane, sugar, ethanol and also the productivity of sugarcane, sugar and ethanol yield as measures of long-term innovativeness.

When it comes to capacity to produce sugarcane, mill sugar and produce ethanol, São Paulo is much larger than the other cases. At the same time it is a larger and more populous state. Cuba's figures for the period 1970–1990 were quite impressive when it comes to production of cane and sugar.

In 1990 São Paulo produced 122.7 million metric tons of sugarcane, whereas the North East produced 48.3 and Cuba 74.8. São Paulo is four times as large population-wise as the other two cases. So in this period the one with the proportionally largest production of sugarcane was Cuba. São Paulo produced 3 million tons of sugar, the North East 2.5 and Cuba 8 million tons. Cuba was the biggest producer of sugar, but the Brazilians and

in particular the producers in São Paulo had begun to produce ethanol in large quantities, 7.8 million tons compared to 1.5 for the North East.

In the production measures, one can observe that São Paulo has been growing significantly, Alagoas some and Pernambuco shrunk but is recuperating and Cuba has from high levels crumbled. The change from 1990 to 2010 is quite radical; sugar production in São Paulo has grown by 181%, sugar production 566% and ethanol 117%, producing eight times as much cane as the North East, five times as much sugar and thirteen times as much ethanol in this period, Alagoas has grown as a producer of sugarcane and sugar and Pernambuco has shrunk, even though it has recuperated from even lower levels at the end of the 1990s. Cuban production in 08/09 of sugarcane was only 21% of what it had been in the 89/90 harvest, and sugar production fell to 19% of what it had used to be; compared to São Paulo's production, which at this time was 22 times as high for sugarcane and 13 times as high for sugar production, it is very low, see Table 21.

Table 21: Production in millions of sugarcane (T), sugar (T) and ethanol (M3)

	São Paulo			Alagoas			Pernambuco			Cuba	
	Cane	Sugar	Eth	Cane	Sugar	Eth.	Cane	Sugar	Eth	Cane	Sugar
69/70	20.4	1.9	0.3	5.7	0.5	0.03	9.6	0.9	0.08	79.5	8.5
79/80	59.8	2.8	2.5	14.6	1	0.2	15.8	1.2	0.2	63.9	6.5
89/90	122.7	3.0	7.8	26.4	1.2	0.9	21.9	1.3	0.6	74.8	8
99/00	197	13	8.5	19.3	1.2	0.6	13.2	0.9	0.3	36.4	4.1
08/09	345.4	20	17	27.1	2.2	0.8	18.8	1.5	0.5	15.8	1.4

Source: ONE (2008a), Perez Lopez and Alvarez (2005) and MAPA (2009)

Note: Cuban ethanol production has been insignificant and is therefore not included in the table.

Changes in production relate to changes in uses of land, but more importantly also to productivity measures. The development of new cane varieties and technologies in processing has led to higher yields of sugarcane from sugar fields, but also from sugar output from industrial processes.

When it comes to yield of sugar and ethanol, productivity levels in Brazil have risen notably over time; from 1970 to 2009, sugar yield grew by 23%, see Table 22.

In the period from 1990 to 2008 sugar yield grew by 10%. For the Centre South the figure is 13% growth from 89/90 to 08/09 and for the North East it is 16%. The North East has been lagging in sugar yield but is catching up, this may be a result of previously non-productive units having been taken out of activity. Ethanol yield grew immensely in Brazil during the Pró-Álcool years, by 446%, and during the 1990s it fell and has risen again during the last decade.

Table 22: Sugar yield Brazil, Centre South, North East, Cuba; and ethanol yield Brazil

	Brazil	Centre South	North East	Cuba	Brazil ethanol
69/70	114			107	10
79/80	116			109	30
89/90	128	125	116	107	54
99/00	140	143	116	111	42
08/09	140	141	135	114	49

Source: Perez Lopez (1991), Perez Lopez and Alvarez (2005), One (2010), Mapa (2009) and SCA (2010)

Note: Sugar yield is sugar output per sugarcane crushed (kg ATR/ton in Brazil and in Cuba yield is presented in percentages, as Sugar 96 as a percentage of sugarcane, which I have here turned into kg/ton to make it comparable to Brazilian numbers) and ethanol is litre per ton crushed cane (l/ton)

The numbers for the aggregate levels of sugar yield in Cuba were initially in 69/70 more or less the same as in Brazil, and there have been minor variations upwards of 6%. Cubans, however, are lagging 23% behind Brazil in sugar yield. The lower yield is also reflected in production costs; Alonso Pippo et al. (2008) have estimated that the production cost of one pound of raw sugar in Cuba is around 0.10 USD/pound of sugar whereas the production costs in Brazil are 0.045 USD/pound of sugar.

São Paulo has the highest number of active sugar plants and distilleries, with a total of 276 units. However, the per capita number of mills is larger in the

North East than in São Paulo. Cuba has the fewest, see Table 23. Regarding Cuba there is potential for more mills; how many is hard to say. Infrastructure-wise Cuba has 61 mills (Nova Gonzalez, 2010). However, in the latest harvests as few as only 42 were used (Mesa-Lago, 2008). Once there were over 150 mills; this was more or less halved in the restructuring of 2003. However, it seems that the number of mills is decreasing every year, and the number in Table 23 is from the figures indicated as being used in the harvest period of 2006–2009. The mills have not been claimed to be the bottleneck in Cuba, but rather the production of sugarcane.

Table 23: Sugar plants and distilleries in 2005

Region	Sugar mills	Distilleries	Plants with distilleries	Total units
North East	8	19	52	79
Centre South	8	59	209	276
Cuba	50		11	50*

Source: MME/ MAPA (2005) and Nova (2006)*

* Note: The number of activated mills is falling every year, possibly reflecting problems with replacing equipment and capital goods, as well as a reduced need due to lower sugarcane yield. In the 2006 harvest only 42 mills were activated (Mesa-Lago, 2008), but there are 61 that can potentially be used (Nova Gonzalez, 2010)

When it comes to the amount of sugarcane produced per hectare of fields grown, São Paulo once again has better numbers than the other cases, and the productivity grew from 76 tons per hectare in 1990 to 81 in 2005, as reflected in Table 24. Average productivity numbers are lower in the North East than in the Centre South, even though individual farms in the North East can meet the numbers in the Centre South. However, the majority of farms in the Centre South have higher figures. Alagoas is also more productive than Pernambuco, and the third best case is Alagoas in 2005 with 61 tons per hectare. Alagoas is also the region that has raised productivity levels most in the data set, from 47 to 61, an increase of 30%. Pernambuco has only marginally increased and São Paulo has grown by 6%. In Cuba the productivity kept on rising until the end of the 1980s, and with the beginning of the Special Period the numbers have fallen.

Table 24: Productivity of sugarcane (harvested tons/hectare)

Year	Brazil	São Paulo	Alagoas	Pernambuco	Cuba
1990	61.5	76	47	49	58
1995	66.6	77	48	49	29
2000	67.9	76	62	50	36
2005	73.8	81	61	51	22
2008	77.5				41

Source: ONE (2008a) and MAPA (2005, 2009)

As reflected by the other measures, Cuba peaked in 1990 and its measure at this time was 58 tons per hectare, which is the fourth highest number, and actually higher than the average in Pernambuco in 2005, which is 51. However, Cuban figures have since fallen sharply to 22, which is the lowest by far, see more in Table 24. The year 2005 was an extreme low, however, and the preceding and subsequent years were slightly better. There have been efforts to reorganise and increase efficiency in the industry, but without much success so far. There is a possible slight recovery in the latest harvests, but it is still increasing from very low levels and it is far from Brazilian levels. In the harvest of 03/04 the yield was 36; in 05/06 the yield was 28 tons per hectare and in the harvest of 07/08 it had risen to 41. This is far, however, from the Brazilian average of 77.5 in 2008.

4.7.5 Qualitative Findings

In this section is a listing of major innovations as stated by respondents and found in literature, sorted into product or process innovations.

4.7.5.1 São Paulo

Product Innovations

In São Paulo a number of interesting product innovations have been developed, related to process equipment for the sugar and ethanol mills, and also for ethanol cars and filling stations that came out of the Pró-Álcool programme. In 2003 flex-fuel cars that run on either pure ethanol or pure petrol or any mix of the two were launched. Technology has been developed by the Latin American division of Bosch and by Magneti Marelli (Hessel Teich, 2006). Almost all large brands have flex-fuel cars in Brazil today, and new car sales in Brazil are around 85% flex cars. Peugeot and Citroen build

their flex-fuel cars in Brazil and then send them to Europe. The Brazilian company Obvio is preparing to build small biofuel sports cars. The Brazilian company Abcesso has developed kits that anyone can install in their petrol car, in order to convert it to a flex-fuel car. Bosch in Brazil has also developed specific fuel pumps for biofuels.

Not only cars can be driven on ethanol, but aeroplanes have also been developed. Neiva, a subsidiary of Embraer, has created an aeroplane, the Ipanema,¹⁸ that runs on ethanol; it takes up to four persons and is mainly used on big farms (Chagas, 2006).

Then there are producers of sugarcane harvesters. Santal in Ribeirão Preto has developed many different and new versions of sugarcane harvesters, as has CASE New Holland in Piracicaba, where new sugarcane harvester technology has been developed. The Faculty of Agricultural Engineering (FEAGRI) at Campinas University (UNICAMP) is developing auxiliary harvesting machinery called the mobile auxiliary harvest unit (UNIMAC), which will partially substitute human labour and increase safety and comfort for harvest workers (Santos, 2008).

Another interesting new product area is bio-plastics. In the 1970s and 1980s, the Dow subsidiary Union Carbide in Brazil already had in-house processes for converting ethanol to polymer-grade ethylene (A. Andrade, 2007). This made no major impact at the time. Currently there are a number of plants producing plastics from ethanol established and a few more are on their way. The major producer is the Pedra Sugar Mill, near Ribeirão Preto, in the State of São Paulo. In 2002 a pilot plant for PHB (polyhydroxybutyrate, an organic composite synthesised by bacteria-eating sugar with properties similar to plastics) was inaugurated, later a dedicated company the PHB Industrial S/A has been spun out (Molinari, 2006). There are further establishments on the way, and in São Paulo the US company Dow and French/Brazilian LDC-SEV will build a plant to produce Poly-ethen products from ethanol, with applications in areas such as food packaging, packaging for personal care and domestic cleaning products and supermarket bags (Jagger, 2007). The Brazilian company Braskem is also building a unit in Triunfo, Rio Grande do Sul, which will

¹⁸ http://www.aeroneiva.com.br/site/content/produtos/produtos_ipanema_apresentacao.asp.

be online earlier but on a smaller scale. COSAN is going to be one of the main suppliers of ethanol for the plant. A second plant will be located in the Centre South (Reuters, 2010a). Braskem has committed to selling 50,000 tons of green plastics to Toyota, which is a quarter of the 200,000-ton production.

California-based Amyris Biotechnologies (developers of chemical and biofuel products from sugarcane) has initiated a partnership with the sugar company São Martinho to develop biodiesel, solvents, and other higher-value chemical outputs, where the value added can be two to three times as high as for ethanol. Amyris in turn has also had an investment by the French group Total, which has bought 17% of their shares, mainly to expand into biofuel, primarily in Brazil.

There has been diversification into products such as crystal sugar, liquid sugar, sugar light, diet sugar, organic sugar, different packages in sizes and packaging materials, new brands, and production of electricity for the grid (Vian et al., 2005).

Process Innovations

Process innovations include automation, quality programmes, mechanisation in agriculture, improved logistics. Furthermore, new technology, such as irrigation systems and new cane varieties, has allowed for the deployment of sugarcane fields in new areas (Vian et al., 2005).

In 1970 Brazil had few sugarcane varieties developed and put in to use, but from the efforts of Planalsucar, CTC, IAC and IB, a broad variety has been developed. In total since the 1970s, there has been an increase from 10 varieties of sugarcane to around 400 sorts. All farmers have 10–15 varieties, to suit soil, humidity and weather; some are better for sugar, some for ethanol, some are better for mechanical and others for manual harvesting. In 1984 the most popular variety, NA56-79, was planted on 43% of the land. This created problems a few years later when there were problems with sugarcane rust that reduced production, as cultivation was too focused on a limited number of varieties and at the same time there had been sharp reductions in public support to sugarcane research in Planalsucar/RIDESA (Simões, 2007a). Today, no variety is used for more than 12.5% of the land. This has substantially increased the yield in sugarcane and the yield of sugar in production. Harvesting seasons have increased from 150 to 220 days (Ueki, 2007). This has also enabled the use of more land types than before.

Another breakthrough has come from the project to map the sugarcane genomics, carried out by the SUCEST network consisting of a number of universities from around the state of São Paulo, which was financed by FAPESP. The project was launched in 1998 with the aim of identifying 50,000 sugarcane genes. It involved 50 data mining laboratories and 24 sequencing laboratories, and after 15 months it delivered 291,904 sequenced tags. The financing for the SUCEST project came from FAPESP and Copersucar, which also served as a data mining laboratory (Ueki, 2007).

Brazil has had (non-commercial) transgenic varieties since the 1990s. This is a basis for developing new cane varieties, but also for a number of new and emerging science-based firms. Important here has been the Votorantim New Business, a venture capital firm, belonging to the Votorantim group (a large Brazilian conglomerate involved in finance, cement, agribusiness, metal, energy, etc.) which has invested in three new businesses involving the top researchers from the SUCEST project and RIDESA. The venture capital firm was also managed by one of the top scientists from the consortia behind the SUCEST project. There are a number of new start-ups, such as Allelyx, originating from Unicamp, who use genetics and genomics in developing agribusiness products and aim at developing new and more targeted varieties. Cana Vialis, headquartered next door to Allelyx, are using genetics and genomics to develop new sugarcane varieties, but also conventional breeding methods, and also provide services of assistance in choosing varieties and management training to mills. Both firms are financed by Votorantim and are located in the industrial district in Campinas. Cana Vialis has a research station in Maceio, in Alagoas. They have contracts with 46 mills, whose production areas is equivalent to 15% of sugarcane plantations in Brazil; among the customers are the Cosan group (Simões, 2007b). Cana Vialis and Allelyx were acquired by Monsanto in 2008 for USD 290 Million (De Carvalho Varrichio and Queiroz, 2010). There is also Scylla Bioinformatica, with its origins in Unicamp in Campinas, which develop bioinformatics (da Graça, 2006).

The São Carlos-based firm Enalta Inovações Tecnológicas base its technology on a PhD project from Unicamp-Feagri. The technology can monitor and measure the productivity of sugarcane production. The technology was developed together with resources from four local universities. The company Bug from Piracicaba is a spin-off from a joint research project between ESALQ, Fundecitrus, Coopercitrus, and the

University of California in Davis (UCDavis). The company specialises in producing insects to combat pests in cultures such as sugarcane, corn, tomato, etc. known as sugarcane borer (Da Silveira, 2008).

The vision of sugar mills, such as Cosan (see Appendix 1), Copersucar (see Appendix 3) and others is to turn themselves into biorefineries, a process which is already on its way, with new business models, operating processes and offerings (Cosan, 2010; Copersucar, 2010; T. Andrade, 2008). Already at this point many of the mills are producing sugar, ethanol for consumption, for automotive fuel and electricity, which is sold to the grid. In the bio-refinery, there would be production of energy, electricity, textiles, biotech, pharmaceuticals, sugar, oil, fertilisers, polymers based on sugarcane as a base material. The sugarcane can be an advantageous material for this, as it has relatively low cost, large availability and an interesting mix of 1/3 sucrose and 2/3 pre-processed ligno-cellulosic material. This can be used for many of the above-mentioned areas. According to Olivério, a senior official at Dedini (Ueki, 2007), the equipment industry has evolved in five big stages of technological innovation: i) an increase in capacity during the 1970s to modernise the sector, ii) an increase in yields, iii) a greater use of sugarcane energy, iv) a greater use of sugarcane products and by-products, v) a change of the mill from sugar/ethanol into a energy and food producing unit.

Dedini, the supplier of process equipment for sugar and ethanol industry, is in the process of finalising commercialisation of the Dedini Rapid Hydrolysis which, when fully developed, will duplicate the current alcohol production per hectare of harvested sugarcane, and will make ethanol competitive with petrol prices of USD 20/barrel (Oliverio and Proença Hilst, 2003). In 2010 an agreement with the Danish company Novozymes, world leaders in enzyme technology, was reached to jointly develop the technology. It will continue to develop it in Piracicaba, and most likely in the location of the Science Park (Santos, 2008).

There are also examples of metal-mechanical innovations from suppliers to sugar and ethanol plants, such as Dedini and Zanzini, which are exported globally, see Appendix 2. There is Smar Industrial Equipment, which is Brazil's main manufacturer of instruments for electronic control of industrial processes that began in 1978 by providing equipment for sugarcane milling for a plant in Pontal, São Paulo (Simões, 2006b). Smar has continuously grown over the years and worked intensely with R&D.

They have 150 employees dedicated to this, 20 patents, and another 30 applications being analysed. Another example is Technopulp, which received a boost from Pró-Álcool programme and began to advance in the sugar and alcohol industry. Initially they were manufacturing equipment, such as purifiers and refiners for mills, but later changed to filters that have since then been the main product (Komar, 2007a).

Clearly there is a wide array of innovations coming out of São Paulo, in both process and product innovations.

4.7.5.2 North East

Product Innovations

The North East of Brazil is not as impressive as the Centre South. Technology is mainly developed in Centre South both by technology firms, as well as R&D institutes. The large sugar mills in the North East then buy the technology and implement it in their processes. There are a few examples of innovations from this region.

The company Implanor was created in 1974, which is specialised in harvesting equipment for hilly terrain. They have evolved over time, from loaders to trucks for carrying cane to sugarcane harvesters. They have offices in Pernambuco, Alagoas and São Paulo, with the first two regions as their main markets (Implanor, 2010). Firms in the North East have not mechanised as much as in the Centre South, both because of more problematic terrain, but also in order to save jobs.

The indication from the firms I met was that they were exploring both process and product innovations to raise productivity (Almeida, 2007; Neto, 2007), see more in Appendix 6. As in the Centre South there is a vision of becoming biorefineries, and many mills are producing electricity, ethanol and gases such as carbon dioxide and methanol (Neto, 2007).

Process Innovations

Another drive is to implement process innovations, such as irrigation, the use of new varieties (pest-resistant, better yields, and prolonged harvest periods), the increased use of processes for reducing fermentation times, larger plants with more automated processes. Soon there will be a radical increase in mechanisation, as the process of burning cane will be prohibited

due to environmental concerns. This has reduced costs, decreased number of employees and raised productivity (Fatima Vidal, 2006).

Most innovations come from the Centre South and are adapted to the North East firms. Locally there are consultants and technology firms, but most often these are local branches of firms that originate from the Centre South (Neto, 2010). For example, Dedini has local offices in both Alagoas and Recife (Ueki, 2007). There are exceptions such as the enzyme company Bioenzima, which produces enzymes for different industrial process, such as enzymes for treatment of denim textile. Bioenzima has patented a process where enzymes are involved in improving processes for creating ethanol from sugarcane, and also from banana plants.

In 2010 RIDESA are launching a series of new cane varieties that are specifically targeted towards the North East that are developed in Pernambuco and Alagoas (Camarotto, 2009). At the Federal University of Pernambuco there is development of a polymer from cane that can replace skin (A. Andrade, 2007).

4.7.5.3 Cuba

Product Innovations

Cuba was successful up to the end of the 1980s, with the introduction of a number of innovations and upgrading of the industry, and one of Cuba's strengths is the knowledge base within the sugar industry. Since this period there has been a drop in innovations and diversification.

Over the years Cuba has built up a science and technology capacity in the sugar industry which has led to the advance of the industry and the development of innovations. Before the revolution there were some 5–10 major derivatives, whereas around 89/90 roughly 40 derivatives had been developed (Zimbalist and Brundenius, 1989). Innovations include, rums, ageing processes of rum (through ozonification), glue, paper board (they have a specific paper production plant), chemical products, yeast, animal feed, new sugarcane varieties, technical services, carbon dioxide, sugarcane harvesters, and many organisational experiments, and there are around 150 subcategories of goods and services that are connected to the industry (GEPLACEA, 1988).

Cuba has developed factories for building sugarcane harvesters, the KTPs, and also metal-mechanical industries to build equipment for sugar mills. In the mid-1990s there were 17 sugar mills with capacity to produce refined sugar, 5 factories for pulp and paper from bagasse, 2 producing bagasse boards, 16 alcohol distilleries, and 23 plants with capacity for yeast for animal feed or human consumption (Pérez López and Alvarez, 2005). Most of these plants worked together with one or several mills, their feasibility depending on the mills' success.

There are, however, a number of authors who have argued that these developments have had limited impact. Pérez López and Alvarez (2005) write that even though there have been plenty of derivatives these have had limited economic impact. Similarly Monreal (2004) argues that even though innovations were created, they have not had any greater economic impact, but it was/is sugar in itself which is the prime sector.

Since 1993, the sugar industry has struggled and little new development of innovations has taken place. However, according to the survey of innovation and rationalisation, improvements of value are being implemented (ONE, 2010), but the patenting rate has radically fallen, and the productivity measures are falling. Furthermore, as there have been great struggles to reach the targets of the plans for the mills, less cane has been available for alternative production. In an article from 2009, Cuban government agencies are said to be planning to reopen plants to restart derivative production, in the article there are indications that the main derivatives have not had a major economic impact (Cubaheadlines, 2009).

The areas where there seems to be growth are in consultancy concerning sugar technology, for example the joint venture Tech Agro between Cuba and Brazilian firms, with customers and offices in a number of locations around the world, e.g. Australia and Brazil (Kerr, 2008). Furthermore, the production and exportation of rum for consumption is increasing, from 2002 to 2008 the production has risen from 709,300 to 960,800 litres (ONE, 2008b).

Process Innovations

Cuba has developed new cane varieties, and introduced new fertilisers and increased the use of mechanical harvesting.

Cuba has an advanced sugarcane breeding programme, which has produced a number of varieties. The major responsibility for the breeding programme rests with INICA (The National Institute for Investigation of Sugarcane). They conduct breeding in 5 provinces at 10 sites and create some 1,500 to 1,800 crosses annually. Cuba conducted a census in 2000 of the use of sugarcane varieties in the island, revealing that the most popular variety was planted in 19.9% of the land and the 10 most popular varieties were grown in 80% of the land, indicating that farms followed the policy of not planting more than 25% of a variety in a farm, to protect against rust and smut (Rossi Machado, 2005). The most popular variety is a local Cuban one, but there are still important foreign ones, like the American CP52-43 that accounted for 7.5% of the land and the B63118 from Barbados that accounted for 3.3%.

There has been increased mechanisation, but it has also fallen over time, as there have been fewer resources to renew the machinery. Likewise, there has been less use of fertilisers, as fewer resources are available.

Cuba has nevertheless produced a number of innovations in the sugar industry, which is also reflected in the quantitative research and also in our interviews in Brazil, where it was mentioned that in the North East they had initiated a project in which they planned to use Cuban technology to develop seedlings for cane (A. Andrade, 2007). One can also see developments within bio-tech, as related to the sugar industry and a potentially important development. When reviewing patents related to sugar, one can see that there is a distinct move towards biotech and medicine. However, it is hard to value how much this relates to the sugar industry, and their mutual needs.

4.7.6 Summary

In a comparison of the different data, São Paulo emerges as the strongest case, particularly after 1990 with high levels of innovations, production and productivity. There is a strong mix of institutions and organisations in place, with research and production capacities, with important links between different stakeholder groups. There is a large strong local market for sugar, ethanol and new derivatives, as well as for advanced technology and services. In the state there are other related and important industries, through which knowledge can be combined in new innovations, such as the automotive

industry and the metal-mechanical industry. The shining example is the local cluster around Piracicaba, with outstanding data in patents and articles.

Brazil has a strong technology base and numerous innovations have been developed, both in agricultural and in metal-mechanical industries. Most technology is created in São Paulo, and this is the case that is the most diversified and with the deepest weave of firms and institutions, with more new ways of organising activities and new offerings. Since the 1970s the innovative activities have increased, and very much so since 2003. The deregulation of the ethanol industry had some initial challenges, but seems to have increased innovation activities. There have been product (new harvesters), process (hydrolysis), market (exportation of sugar mills, ethanol as automotive fuels) and organisational innovations (Consecana system for negotiation of sugar prices). There are both incremental innovations such as improvements of sugar refining processes, and more radical innovations such as ethanol as car fuel, and also turning sugar mills into biorefineries. These more radical innovations also originate from São Paulo. The Pintec survey likewise indicates that São Paulo is generating much more innovations than Pernambuco, to a greater value, and more innovations that are new to the market (IBGE, 2010).

The North East is double-sided; Pernambuco's sugar industry has shrunk, Alagoa's has grown somewhat. The Pintec survey indicates that firms are innovating, but to a lesser degree than in São Paulo. Also, collaboration and use of R&D resources seems to be even less important than in São Paulo; the main sources are through purchases of equipment and software. This may also explain the lower numbers of other innovation indicators such as patents. The innovation indicators in the form of patents and articles are very low, as are qualitative indicators; for example, researchers from the city of Piracicaba alone have produced more patents and articles than all of the North East together. The number of articles is growing, though, but from very low levels. There are some innovations originating from the local specific conditions, such as the Implonor sugarcane grabber, some process innovations, and the development of new sugarcane varieties from the RIDESA network, with varieties tailored to the needs of the North East region (Camarotto, 2009). Qualitative data imply that firms are innovating, however; through new offerings such as electricity and ethanol, but also through the implementation of new production measures, such as irrigation and new cane varieties. In the future there will most likely be more

mechanisation as well. Much of the technology comes from non-local resources such as suppliers and consultants, often with their origin in São Paulo or CTC. The North East is also producing more cane, sugar and ethanol than Cuba, and productivity numbers are higher than Cuba, but scientific capacity is lower.

Cuba was quite successful up to the Special Period, with the introduction of a number of innovations and upgrading of the industry; since that period there has been a drop in innovations and diversification, as indicated by patents and scientific articles. The Cuban survey of innovations and rationalisation indicates that innovation is taking place in the sugar industry and that the economic relevance of the industry is relatively important, as it stands for around 14% of the value of all innovations generated. At the same time the number of innovations and rationalisations has fallen to a third from 2005 to 2009, and the sugar industry's share of the total GDP has fallen in the same period from 4.9% to 3.8%. The survey data are however somewhat uncertain as regards what is really being measured. A number of scholars have also argued that the value of Cuban innovations has been marginal and that the greatest value has been in sugar production (Monreal, 2004; Pérez López and Alvarez, 2005). The sugar industry has crumbled and production capacity has shrunk drastically; productivity figures have gone through the floor. There is a notable capacity when it comes to scientific articles, and there are still some patents filed. However, regarding scientific and patent output, the interest seems to be transforming towards biotech and pharmaceuticals.

From all of the cases the indications are that the importance of patents and scientific and technology resources has grown over time. The number of patents and articles has grown in Brazil; also, the ethanol industry in Brazil is increasingly using internal R&D as an activity for innovation. In Cuba patents have decreased and articles are increasing, but not as much, which may be a result of the reduced political interest in the industry, and the structural challenges, as well as an interest in diverting resources and focuses elsewhere. Still when it comes to patents and articles Cuba has a high capacity when compared to the size of the population. The weakest case is the North East, which has very few patents and articles.

In the patent analysis we could see that in Brazil there has been a move from products towards process patents, but not in Cuba. Also, the data from the

Pintec survey indicate that process innovations are the most important ones, especially for the ethanol industry, less so for the machinery and equipment industry (IBGE, 2010).

I have not been able to make a system to classify patents in groups of radical or incremental innovations. However, when reading the patent descriptions one can see that there are not many that would be classified as radical innovations, in that they are system changing, neither in Brazil nor in Cuba, with the exception of the possible potential of the Dedini rapid Hydrolysis, which could have radical implications for ethanol production. However, when reviewing the Pintec data and the qualitative data for innovation outcomes, it seems as if Brazil and in particular São Paulo has generated and implemented more radical innovations, which have widespread and systemic implications for the sugar industry, such as systems for ethanol as automotive fuel, flex-fuel technology, burning of bagasse to produce electricity for the grid, and mapping of the sugarcane genome. The suppliers also seem to have generated more new innovations than the ethanol industry, as suggested by the Pintec data, whereas the North East is concerned with more implementing technologies (both product and process innovations though) and creating incremental innovations. Likewise, Cuba generates more incremental innovations and despite that patents are mainly in product innovations, seem to a greater extent be implementing process innovations. However, in the 1970s-1990s a wide range of technology for different derivate products was developed.

The different cases have been classified in table 25 on a scale of one to three, where three is high, as follows: i) knowledge generation, which is an overall estimation of indications of innovation from qualitative sources, patents and scientific articles; ii) types of innovation (product or process) indicates which kind dominates in the region, based on innovation survey and patents; if a case is indicated as having radical innovations it also has incremental ones, whereas incremental ones do not have radical innovations; and iii) Innovation implementation is based on the innovation survey data and output factors such as production and productivity measures of sugarcane, sugar and ethanol that together indicate how well innovations and upgrading affects industry over time.

Cuba has scientific capacity (Alonso Pippo, 2008) and has created some patents, but when one compares figures of productivity, Cuba's numbers are

falling, and the Centre South has higher productivity numbers than the North East, even though there are islands in the North East that can meet the productivity levels of the Centre South (Almeida, 2007).

Table 25: Characterisation of innovation in cases

Case	Knowledge generation (1–3)	Types of Innovations	Innovation (1–3)
São Paulo →1990	2	Product & Radical	3
São Paulo 1990→	3	Process & Radical	3
North East →1990	1	Process & Incremental	2
North East 1990→	1	Process & Incremental	2
Cuba →1993	3	Product & Incremental	3
Cuba 1993→	2	Process & Incremental	1

In the comparative analysis, a picture emerges of the strong case of São Paulo that mixes innovativeness with efficiency, where there is present growth, with future potential. The North East has stumbled and shrunk, but will eventually come out of the restructuring with an improved capacity. Cuba used to have a capacity, and innovations, but lacks efficiency. However, a lesson could be that for long-term productivity it is important not only to have innovation, but also efficiency.

4.8 São Paulo Institutional Arrangements

In the following three sections data will be sorted into the analytical framework that connects institutional arrangements with cluster externalities. At the end there will be a summary of each case with regard to how institutional arrangements have influenced cluster externalities that have an impact on innovation.

4.8.1 Market Arrangements

4.8.1.1 Intense Competition

Up to the 1990s the sugar and ethanol industry in Brazil was strictly regulated, and issues of the industry were managed by the IAA institute. IAA regulated sugar prices and set quotas of production of sugar and cane from 1933 to 1997 (Roque de Oliveira, 2008). The IAA act also decided whether new sugarcane mills could be established (Signorini et al., 2010). Before 1990 the way firms operated and the product mixes they offered were very similar; the state intervention reduced competitive pressures. Also there was a practice of technology development in state organisations that also spread best practices between firms in order to improve productivity (Vian, 2006; Storel, 2006).

Since deregulation there has been first a turbulent period, with both establishments of new units and many old ones going bankrupt, notably in 1997–2000. There has been an influx of many new actors and a spread to new regions, as well as processes of mergers and acquisitions (Zylberstajn, 2006; Storel, 2006). In the last few years there has been an expansion in the sugar industry, with a growth in the number of firms and establishments. Existing strong firms buy up smaller ones; there are also a number of totally new investments, with the creation of new firms and foreign firms investing in Brazil (Zylberstajn, 2006). Around 100 new mills are on their way in the next few years, and 40 are currently being constructed. There is investment from sugar firms and venture capital firms, with 12 international organisations planning to set up mills, from the EU, the USA and Japan (T. Andrade, 2008). There are also groups from the North East that are establishing themselves in the Centre South (A. Andrade, 2007). Since 1990 competition has increased, and even though there has been a fierce process of mergers and acquisitions the concentration of firms in São Paulo

decreased between 1992/1993 and 2002/2003 and there are fewer dominant firms (Vian et al., 2005).

Since deregulation the sugar industry has grown in the south of the country. According to some of the respondents, deregulation has spurred firms to innovate, by developing new process technologies, increasing scales, providing new offerings in new markets, and to increase productivity (T. Andrade, 2008; Roque da Silva, 2008). Process innovations include automation, quality programmes, mechanisation in agriculture, improved logistics. Furthermore, new technology, such as irrigation systems and new cane varieties, has allowed for the deployment of sugarcane fields in new areas (Vian, 2006). There has been diversification into products such as crystal sugar, liquid sugar, sugar light, diet sugar, organic sugar, different packages in sizes and packaging materials, new brands, and production of electricity for the grid.

Furthermore, there has been restructuring of firms by moving into new economic activities in forward and backward linkages; e.g. some firms have increased land owning and focused on growing more cane themselves, some pure sugar or pure ethanol distilleries have begun to supplement their production with the other form, and others have diversified into producing inputs to sugarcane growing processes. Another strategy has been to move into forward linkages, such as the production of chilled drinks, to which they have sold their production and synergies with juice production, cakes and cookies (Vian et al., 2005). One interesting example is Cosan, which has formed a joint venture with Shell where they will pool retail operations and globally they will use Shell's sales network, see Appendix 1. Cosan recently bought Esso's filling station to become a complete provider of ethanol (Dobosz, 2009), which they will bring into the operation. The joint venture will invest more resources to increase output. Into the venture Shell will also add a Canadian subsidiary that develops technology for making ethanol from straw (Economist, 2010a).

With regard to cluster-specific competition, respondents did not acknowledge that there was a personal local rivalry that drove competition in and around the Piracicaba cluster (Santos, 2006; Sartori, 2008). If there was any such socially motivated competition, it was more between São Paulo and the North East (T. Andrade, 2008). However, it seemed to confirm Boari et al.'s (2003) observation that competition is not blind, the

respondents with whom there has been interaction seem to be knowledgeable about competitors and market actors, in both the Centre South and the North East, and for millers as well as suppliers, and seem to have an opinion about the activities of competitors (Almeida, 2007; Nieto, 2007; Santos, 2006; Sartori, 2008; T. Andrade, 2008). Furthermore, an examination of the material found no indications of the importance of transparency in competition and its role for more intense competition in this case.

At the same time, the growth of the cluster is creating challenges, with problems in infrastructure, labour and utilisation of research resources. Much of the sugar industry in São Paulo is located in the inland and is negatively affected by poor infrastructure, with increased use of the capacity. Even though there is a centre and concentration of skilled labour in Piracicaba, there are also problems with labour shortage and in particular for skilled labour for sugarcane harvesting and the metal-mechanical industry (Sartori, 2008), but also for manual harvesting (Santos, 2008).

There are also worries among researchers that the current boom diverts the focus of research on immediate matters, and too few resources and researchers are devoted to more long-term and more basic-science-oriented projects, which can damage long-term competitiveness (Inovação Unicamp, 2006a). The situation is better in São Paulo, where there are strong connections between industry and CTC, and more newly started companies that develop new technology, but worse in other parts of the country. The researchers argue that universities, research institutes, foundations and agencies are more important than ever, and of particular importance is the development of new cane varieties, for which it took ten years to get the first results, and now it is important to develop varieties for increased use of mechanised harvesting (Inovação Unicamp, 2006a). There are also fears that Brazil is not investing enough in the second generation of biofuels and that the US will establish their technology, as they have more scientific capabilities, and there is an overall criticism that there is not enough investment in more basic science with more radical potential; the view is that there has been more investment in engineering and for incremental solutions (Simões, 2007a).

4.8.1.2 Knowledge Spill-over

Before the 1990s competition was limited, and there were not so many new firm start-ups; there was more of a process of firm growth and consolidation in the industry. There were some start-ups in industries that supplied technology to mills, as a response to the growing ethanol industry, with new firms such as Technopulp (Komar, 2007a).

Since deregulation, however, more firms are active (Vian et al., 2005) and there have also been start-ups in new activities. New start-ups spun out of established organisations, firms and research institutes include Allelyx, Cana Vialis and Scylla Bioinformatica (da Graça, 2006). These organisations also recruit from universities and other firms, further enhancing knowledge spill-over. Cana Vialis recruited a large share of its employees from the RIDESA programme (Simões, 2007b). The rotation of labour creates knowledge spill-over. There is also rotation between the firms in the metal-mechanical industries in Piracicaba that facilitates spill-over effects (Sartori, 2008).

Increased competition can also lead to new firm start-up in other ways, through laid-off personnel and spin-outs. In the municipality of Sertãozinho close to Ribeirão Preto, with a population of less than 100,000, there are seven mills producing sugar and alcohol, and 450 companies (90% of the total number of firms) active in the sugar and ethanol industry (Simões, 2006b). The industry here has benefited from spin-outs from existing operations. Growth took off with Pró-Álcool, but has increased substantially in the last few years. Immediately after the closure of Pró-Álcool, there was a crisis that resulted in mergers and forced companies to lay off many workers. As an outcome many new firms were started that became suppliers or provided maintenance services. These start-ups are now growing and have become high-technology exporters themselves. There has been differentiation through innovation of products and processes. Firms include the sister companies of B&S and JW that design and build equipment around processes of extractive distillation with ethylene glycol. There is Sermatec, which makes diffusers, used in extracting sugarcane juice, and boilers. Their technology is co-developed with local partners Uni-Systems and HPB. Another example is DLG Automação Industrial, which was founded in 1997 by former employees of the automation company TLK that got some capital and equipment, as compensation, which gave the basis for starting the company. There were also some market opportunities, as firms in the region lacked a regional supplier of peripheral automation parts

(Komar, 2007b). They also benefited from supplying to the local firm Smar Equipamentos Industriais, who supported them from the beginning, as there was a perception of complementarities of solutions.

4.8.1.3 Specialisation

In the period before deregulation, there was some specialisation, but not driven primarily by market arrangements. There was much consolidation in the sugar industry (Zylberstajn, 2006). There was some specialisation and diversification, due to increased demand for ethanol. The production mix went from 85% sugar and 15% ethanol to 27% sugar and 73% ethanol, see Table 7. The drive was mainly public demand signals, but these were transferred as demand signals from mills to suppliers, such as Dedini, which developed new process technologies. There was also an increased demand for innovations from car manufacturers and related industries to develop new technology to be able to create an infrastructure for ethanol-driven cars (Martines-Filho et al., 2006).

In later years specialisation has increased, with many more firms and in more specialised niches. Olivério, the vice president of Dedini responsible for technology development, answered in an interview about what the driver of Dedini's successful growth was; he said it is the market demand that has changed, and it is not due to industrial policy, technology or foreign trade (Inovação Unicamp, 2007).

There is also more specialised labour, which is attractive for foreign investors seeking to establish themselves in São Paulo and Piracicaba. In Piracicaba, there is a broad set-up of actors from all parts of the value chain, with much division of labour and specialisation. Despite the fact that there are mergers and acquisitions going on, this process is increasing, with interesting examples of start-ups such as the company BUG, specialising in pest resistance (Da Silveira, 2008), new plastic companies PHB (Molinari, 2006) and cane companies Cana Viallis and Allelyx (Simões, 2007b).

The concentration of specialised job opportunities and specialised labour seems to be attractive for investment in clusters and conducive to innovation in the clusters. That knowledge is tacit, and labour not frictionlessly mobile, seems to be correct. There are examples of firms leaving the cluster, but with the labour remaining, as presented above concerning Sertãozinho. In Piracicaba the co-operative CSJ Metalúrgica (see more in Appendix 5) was

started by former employees when the company they worked for went bankrupt. Similarly the firm TGM from Sertãozinho grew from seven to 50 employees when they picked up former employees from a local competitor, as that firm moved to the Greater São Paulo area (Simões, 2006b).

Foreign and national actors are interested in locating in São Paulo, not only because of better climate conditions and high productivity levels, but also because around São Paulo, and in particular in Piracicaba, Campinas and the city of São Paulo, there is very competent and skilled labour, with high-technology competence and strong research capabilities. The unique local knowledge makes it attractive for firms to locate there. For skilled labour it is also attractive to move for the jobs offered there (Amaral, 2006; Santos, 2006). As outside firms tap into the local knowledge they also bring new resources to the cluster. There are firms that are locating in Piracicaba, such as Caterpillar and the Danish firm Novozyme, investing in Dedini Rapid Hydrolysis, which has also declared that it will locate research in the Science Park that is to be built (Castelar, 2008). There is also South Korea's CJ group, which is investing USD 600 million in a lysine plant in Piracicaba and related activities in Brazil. CJ group invests in São Paulo in order to take advantage of the country's technology and low-cost sugar production. A competitor, Japan's Ajinomoto, is already established since a few years back in São Paulo with a plant for lysine production (Inovação Unicamp, 2006b). Furthermore, Bayer CropScience has made a deal with CTC to collaborate on biotech for sugarcane varieties to improve ethanol yield by about 30–40% (Bayer Crop Science, 2010).

As the EU trade protection against sugar is being dropped, large European firms are increasingly interested in investing in Brazil. The French sugar firm Luis Dreyfuss has bought the Brazilian company Crystalsev (the new company name is LDC-SEV) in order to establish in Brazil to benefit from the high productivity possibilities and the knowledge base. Shell and Cosan are forming an alliance, see Appendix 1. Açúcar Guarani, owned by the French Tereos group (which at one point had ownership shares in Cosan), has invested in local mills to make it Brazil's third largest group. Also, the state-owned energy and oil company Petrobras has taken a 45.7% share of Guarani, as a response to the Shell and Cosan plans (Reuters, 2010b).

There is not only competition between mills and metal mechanic suppliers, but also between the four main research centres focusing on sugar and

ethanol: CTC, RIDESA, IAC and Cana Viallis. This is endorsed by the representatives of the institutes, as it creates a greater variety of technology for the sugar producers and a broader set-up of varieties planted, which increases resistance to pests, prolongs harvesting periods and increases yields with cane more appropriate for different soils and climates (Simões, 2006a, 2007b). The rivalry drives the labs to produce better results than their competitors and to seek out different niches. The institutes have been described as differing in the following way: CTC is the leader in strategic technologies and exploring new technologic routes, RIDESA is strong in classical improvements and basic research, IAC comes third and is competitive in some niches in the development phase, and Cana Viallis is fourth, but with a great potential in the area of biotechnology (De Carvalho Varrichio and Queiroz, 2010).

4.8.1.4 User-Producer Learning

As an outcome of the Pró-Álcool programme the demand for ethanol increased and mills increased their demand for new process technology, creating opportunities for the metal-mechanical industries. The close connections in Piracicaba between tech firms like Dedini and sugar mills like Copersucar and Cosan supported the development of new technology and CTC (T. Andrade, 2008). Dedini, the leading sugarcane technology firm, grew out of user-producer learning. It began as a repair shop for imported metal mechanics founded by the Italian immigrant Dedini (Dean, 1968).

Local demand and relations are important; 82% of the ethanol production in Brazil is consumed locally, whereas 66% of sugar is exported (Unica, 2010). Local demand has created great influences for expanding the industry and driving investment and innovations in the industry.

Not only local demand is important, however, but also the international system. This is under change with the removal of quotas and tariffs that have restricted the development of the Brazilian industry, both because it has been more expensive to buy Brazilian products due to tariffs, but also because the EU has subsidised the export of European sugar, making it tougher for the Brazilians to compete in world markets. The system has also been such that goods with higher degrees of value added have had higher tariffs, which has benefited the exportation of raw sugar which is later refined in other countries (Schmitz et al., 2005; Frandsen et al., 2001).

International market relations are also affecting Brazilian firms in another way. Brazilian sugar firms are rebranding themselves as biorefineries with sustainable energy. In this process where they position themselves as society-friendly firms, many undertake certification and corporate social responsibility programmes to create a trustworthy image (Amaral, 2006). The sugar industry, with its origins as a slave industry, has a bad historic reputation continuing to the present day. There are many horror stories of low wages, abused labour and landowners forcing settlers away so that they can take over land (Piros Kovacs, 2007; Arruda, 2007; Mazzoldi, 2008) and there is a media picture in the west that Brazilian firms are abusing the labour and destroying rain forests. This image is something that sugar organisations want to counteract, and therefore they are developing certification programmes to try to build trust around the production of ethanol in an ethically acceptable way; there are also international campaigns.

4.8.1.5 Joint Action

I have not found any indications of how market mechanisms have supported joint action.

4.8.2 Network Arrangements

4.8.2.1 Intense Competition

Brazil has had a long period of corporatism, when it was mandatory for firms to be part of different organisations and certain relations were compulsory. Furthermore, the sector was regulated by the IAA, which interacted with the leading firms of the industry and its representatives, running the sugar system in a corporatist way (Armijo and Kearney, 2008).

The sugar industry has always been influential and able to exert strong influence on the government for support (Storel, 2006). One of the respondents also stated that the formation of the IAA was an outcome of industry lobbying (Evangelista, 2007). There are indications that there were problems with networks of vested interests, reducing competition and protecting incumbents (Storel, 2006; Cardoso, 2006; Gomez, 2007; Armijo and Kearney, 2008) and diverting government resources to support the sugar industry. The networks around sugar and alcohol, both informal and formal ones like industry associations, and resources at CTC, influenced the

state to carry out the *Pró-Álcool* and *Planalsucar* programmes (T. Andrade, 2008) that favoured the sugar industry and in particular the incumbent actors.

At present there are numerous networks in the sugar industry. However, these seem more directed to opening up possibilities for innovation, rather than preventing new coming technology. At the same time they are lobbying for different measures of support, such as procurement rates of ethanol, subsidies for flex-fuel cars and for lobbying international trade schemes (Armijo and Kearney, 2008). The policies in São Paulo, compared to other parts and especially since the 1990s, have been more market-oriented. There is less interest in returning to old policies with corporatist regulation of market relations (Cordeiro, 2006; COSAN, 2010). For example, the sugar growers' association of the North East was preparing a lobbying campaign to make it mandatory for sugar mills to buy 40% of their sugarcane from independent growers (Morais de Andrade Lima, 2006), a proposal that the growers' association of São Paulo was not interested in working for. In São Paulo they were not interested in returning to regulated practices but preferred market and network arrangements (Roque de Oliveira, 2008), which they saw as more beneficial.

The suggested affect of local rivalry and collaboration due to community sentiments has not been confirmed by respondents. If anything, in local networks they are based on shared industry interests and long-term interaction, rather than community sentiments (Santos, 2006; Sartori, 2008).

4.8.2.2 Knowledge Spill-over

There has been spill-over, through both informal and formal networks such as networks of metal-mechanical suppliers to Dedini (Freies, 2006; Ribeiro, 2006), local informal networks of major actors such as COSAN, COPERSUCAR, Dedini and Caterpillar (Vian, 2006; T. Andrade, 2008) and strategic alliances like Copersucar (Copersucar, 2010). These relations have been beneficial for innovation in the form of knowledge diffusion in informal exchanges, formal commercial collaboration, but also from the creation of joint R&D capabilities that have developed new technologies and sugarcane varieties (T. Andrade, 2008).

One of the most important alliances here is the CTC, which was spun out of Copersucar in 2004. This decision was taken, as it was perceived that CTC could not hide technology from others and it instead it was better to open up CTC for everyone in the industry. Members pay a fee based on their size and have free access to the technology. CTC get directions from their owners and either they import technology or if there is not a supplier in an area they develop it. They are important for diffusing knowledge between members (T. Andrade, 2008). CTC has also been an important initiator of the development of new technology, such as plastics from sugarcane. In the development of plastics it was not only the networked centre, but also actors from the network that the centre had collaborated with in the research process of Pró-Álcool, that facilitated the process. In the plastics process there was initially collaboration between CTC, the Institute for Technological Research (IPT) and the Institute of Biomedical Sciences of the University of São Paulo (ICB/USP) and it was initially financed by FINEP. Later on in the process, it became more complex with more actors involved. Of key importance was Usina Pedra, which agreed to take a financial risk and invest in a pilot plant for sugarcane plastics (Velho and Velho, 2006) and currently a separate company has spun out of the process, the PHB Industrial S/A (Molinari, 2006); see more about the process in Appendix 3.

Piracicaba has the densest concentration and the most advanced R&D institutions in the Brazilian sugar industry. These institutions provide education, but also create formal and informal networks by studying together (Vian, 2006). There are also strong networks between firms and public research centres, state and federal universities, with some mills functioning as open-air laboratories, where they can test new cane varieties, new equipment, process technologies and organisational practices. At the same time, the mills are the greatest benefactors by receiving adapted technology (Eid and Scopinho, 1998). Researchers from the university work as consultants for the industry and in joint R&D projects, further fostering knowledge spill-over (Vian, 2006; Inovação Unicamp, 2007).

There is also spill-over from university research projects that are picked up by industry and commercialised, which has become increasingly popular. One contributing factor, besides market demand and the availability of venture capital, is the PIPE programme (Technological Innovation in Small Business Programme) from FAPESP, which finances academy spin-offs and

business development involving researchers, such as Enalta Inovações Tecnológicas (Bueno, 2006) and Bug (Da Silveira, 2008) that has collaborated with a large number of university units in developing the technology.

4.8.2.3 Specialisation

Network arrangements are not providing incentives for innovation, but rather enabling it, such as associations creating and diffusing innovation among members or educating employees, or by providing new types of services. These types of networks are an important way of reducing individual costs and addressing common needs, for more specialised labour and knowledge for their operations which the individual actors cannot afford to develop by themselves; one such example is CTC, which has increased the R&D capacity of its members, first the ones from Copersucar and later to all members, and provided specialised services in the sugar area (T. Andrade, 2008); another one is ORPLANA, the sugarcane growers' association in São Paulo (Roque de Oliveira, 2008).

ORPLANA is an association for small farmers, with 13,500 members. They have credit banks, a consultancy arm (Canagro), provide educational courses in order to facilitate upgrading of members' usage of technology and practices, and they undertake lobbying of the government. Unlike their counterpart in the North East, they are not interested in returning to government controls, according to their technical advisor Roque de Oliveira of ORPLANA (2008).

Network arrangements are also behind educational and research facilities that foster further specialisation and upgrading of firms and labour. An example is CIESP (The Confederation of Industry in the State of São Paulo), which is a member of the Brazilian National Confederation of Industry (CNI), and which is behind two important organisations for training in Brazil: Sesi (the Industry's Social Service) and SENAI (The National Industrial Training Service). Every year, SENAI trains 2.8 million professionals and 30 million have enrolled in more than 58 years (SENAI, 2010). CIESP is involved in APLA, and carries out capacity-raising activities (Santos, 2006).

4.8.2.4 User-Producer Learning

The common process for development of metal-mechanical innovations in the sugar industry has been through network-based long-term interaction between sugar and ethanol producers and machine manufacturers, where the millers provide manufacturers with physical space to test their new technologies and provide feedback on technology, while manufacturers provide the financing and the research team (Ueki, 2007). Much of the creation of equipment is tailored to the needs of the specific mill, even though it is based on accumulated knowledge in the supplier (Inovação Unicamp, 2007 and Sartori, 2008). The process seems to be stepwise, as things begin with smaller units that are gradually increased until things works on an industrial scale. This is a process that benefits from long-term business relations, where not everything is specified in a contract

4.8.2.5 Joint Action

Piracicaba has a strong presence of many types of networks, associations and alliances, which have been important for enabling innovation and the growth of the sugar cluster. There are many informal networks around the city, involving persons located in the municipality, the firms, and the university (Vian, 2006; Estacio, 2006; Ribeiro, 2006; T. Andrade, 2008; Amaral, 2008). These types of networks have greased relations and enabled the setting up of collaborative efforts, e.g. CTC and APLA (T. Andrade, 2008), but also in order sharing between Dedini and CSJ Metalúrgica (Sartori, 2008). However, respondents did not acknowledge that it was community-based networks that were underlying joint action, and served to monitor processes, but claimed that these were personal networks evolved from long-term professional relations (Amaral, 2006; T. Andrade, 2008; Sartori, 2008).

Copersucar is a strategic alliance with the original purpose of dealing with R&D, distribution, marketing and sales. Copersucar grew out of the social capital and informal contacts that existed between a number of sugar millers and began as a co-operative of sugarcane producers and the largest sugar and ethanol producers in Brazil (Vian, 2006). CTC began inside Copersucar, in the 1970s, as their internal R&D laboratory. CTC has been very important for joint action in Piracicaba, by setting up joint innovation projects and also by supporting other networks, such as APLA and one of the initiators of the Pró-Álcool scheme (T. Andrade, 2008).

The networks between CTC, Dedini, Copersucar and ESALQ have been important for the development of Dedini Rapid Hidrolisis. Initial research was done in Dedini and they have gradually begun to involve other capabilities, such as CTC for pilots, and ESALQ for basic research, and Copersucar when scaling up. The latter has also provided financing of some BRL 500,000 to set up the pilot unit. The project has also benefited from the relations with the state agency for financing of research projects, FAPESP and the PITE programme, which has provided financing of BRL 1.76 million (Inovação Unicamp, 2006d). CTC is also at the centre of new joint innovation projects like the Biomass gasification project, a joint project between CTC, Dedini, Unica, the private companies Braskem and Oxiteno, and public research institutes (IPT and IPEN); the project is supported by public financing from BNDES (65%) and FAPESP (De Carvalho Varrichio and Queiroz, 2010),

It is common for Brazilian firms in the sugar industry to seek alliances. Among mills 58% have had an alliance, and 44% had one in 2009, and of these 50% had more than one alliance. Of the alliances, 77.8% were with Brazilian companies only, 5.6% with multinationals only and 16.7% with both Falk et al. (2009). Firms look for a recognised brand, markets, capabilities in product development and export distribution, as well as technological know-how/knowledge.

At the same time there was a double message from respondents with regard to collaboration. One response from firms to APLA was the appreciation of the network for having reduced distrust and fostered relations between actors, which increased collaboration (Sartori, 2008; Castelar, 2008). At the same time there are many indications from other respondents that particularly in São Paulo there are many networks in place, both formal and informal, that are behind both innovations and new social innovations like APLA and Uniduto. But also that there are long-term established relations, for example between DEDINI and COSAN and Copersucar, and when Dedini sells equipment to these refineries it is always partial innovations as these are adapted to local conditions (Inovação Unicamp, 2007), and this is the case for CSJ Metalúrgica, when they sell to customers, but also when they sub-supply to DEDINI as seller of the total solution (Sartori, 2008). The knowledge is not so much based on patents (although there are some), but on the tacit engineering skills of the employees. While this process may not be considered by respondents to Pintec as collaborative innovation, as

they perceive that they are purchasing equipment, it is nevertheless a dual process, where input from both sides is necessary.

The respondents to the Pintec survey (IBGE, 2002, 2010) state that firms innovating in the ethanol and coke industry do not regard collaboration as highly important for innovation, and numbers are falling, from 26% in 2000 to 11% in 2008. Most importantly, however, if they were to collaborate it would be with universities, followed by consultants and suppliers (at the same time the number of actors is so low that one or two more cases changes the picture, and therefore these numbers are not completely reliable). For the machinery and equipment industry, innovating collaborating firms are proportionally fewer in 2008 than in 2000, falling from 14.2% in 2000 to 13.9% in 2008. The most important partners for innovating firms were customers 4%, suppliers 2.9% and consultants 4.1%. Compared to the EU it is lower, but not radically lower; in the European Community Survey the average for collaboration among firms is 17% (Brito and Mello, 2006).

However, the main activities for innovation among ethanol and coke firms are acquiring machinery and equipment 70%, training 51% and acquiring software 40%, whereas internal R&D is only 21.2%, a figure that has grown from 4.5% in 2000. For equipment and machinery suppliers it was buying machinery 58%, software 32% and training 36%. These are activities that are not strongly correlated to what could be perceived as direct collaboration, but as mentioned above they may entail components of collaboration which are not perceived by the innovating firm.

Furthermore, there can be impetus to innovation through network relations that are beyond formal collaboration; it seems as if external sources are highly important for innovation, often more important than internal sources. For ethanol and coke industries in 2008, the most important sources were customers 62%, information networks 53%, and then internal non-R&D sources were 54% (internal R&D was only 7%). For the equipment industry the figures were information networks 54%, internal sources non-R&D 48% (internal R&D 12%), customers 46%, trade shows 40% and suppliers 33%.

Networks are also arranged to address specific problems and as more broadly based deliberative organisations. There are challenges with infrastructure and a high demand for skilled and semi-skilled labour, creating problems of

congestion. A number of network organisations are working to address these challenges, such as UNICA and APLA, which have connections through local relations, even though UNICA is growing geographically.

UNICA is the major organisation in Brazil for the sugarcane and ethanol industry. It is located in São Paulo, where most of its members are from, but includes members from all over the country. It was created in 1997 as part of a consolidation process that came out of the deregulation of the market. The organisation has around 130 members, who answer for more than 50% of ethanol produced in Brazil and 60% of sugar production. They work with lobbying; e.g. one issue is to influence Brazilian states to co-ordinate VAT for ethanol at the same low levels of São Paulo. UNICA is also active together with the Brazilian government to lobby the WTO (Cordeiro, 2006). UNICA offers consultancies to other countries' governments on how to develop sugar and ethanol industries, as well as how to use ethanol as a biofuel. Their strategic outlook is that they have a very large domestic market, and that it is not the case that exportation of ethanol in itself will necessarily be the most important source of revenue (Cordeiro, 2006; Amaral, 2006), but other parts of knowledge and machinery for developing other countries' ethanol industries, if a global market for ethanol can be established (Amaral, 2006).

Since deregulation, when the previous system for price regulation and commercialisation was removed, new organisational innovations have occurred, such as new smaller groups emerging for common commercialisation and new common purchasing systems (including online trading) (Vian et al., 2005). Highly important is the Consecana network mechanism to manage sugarcane prices, resolved in negotiations between representatives of the millers in the form of UNICA and representatives of growers in the form of ORPLANA, with voluntary participation. The Consecana system handles and calculates prices for sugarcane, based on global market prices for different types of sugar, and it gives guidance on the price for cane, which is calculated from the sugar content of the cane. There is a monthly meeting at ESALQ in Piracicaba, where the prices are decided. On the price system board there are representatives of UNICA and ORPLANA, and one group with economic expertise and one with technical expertise (Roque de Oliveira, 2008).

In Piracicaba the cluster initiative of APLA has been launched as a deliberative platform for addressing a number of issues and opportunities facing the sugar industry. The early discussions of the APLA began in the CTC, between people from CTC, Dedini, Caterpillar, ESALQ and the local government (Santos, 2006; Stipp, 2006; T. Andrade, 2008). The actual process and areas that the organisation addresses are described in Appendix 4. The respondents claimed that one of the most important benefits of the APLA had been to further improve networks, by increasing familiarity between actors, and that collaboration outside of the immediate APLA activities had increased, such as order sharing (Castelar, 2008; Sartori, 2008).

There is also a network of over 88 industrial plants associated with 10 major ethanol-producing groups¹⁹ that came together in 2008 to form Uniduto Logística S.A., which is a company that aims to improve the logistics situation for Brazilian-produced fuel. They will build a private pipeline transportation system with collection and distribution terminals and ports for transportation of liquid fuel, especially ethanol, and eventually other fuels including biodiesel, and gas. The project comprises the construction of a pipeline and will integrate different means of transportation, e.g. railways, highways, rivers, sea and air. There will also be four collection centres, distribution centres and a proprietary offshore port in the Santos region. The port facility will be able to handle large tankers for shipping ethanol. The system will be up and running by 2013 (Uniduto, 2010).

4.8.3 Quasi Hierarchy Arrangements

4.8.3.1 Intense Competition

Quasi hierarchy arrangements have not enhanced competition or made it more transparent. If anything they have pressured weaker actors, and in combination with networks and state arrangements decreased competitive pressures through their influence on previous policy regimes (Storel, 2006; Gomez, 2007; Armijo and Kearney, 2008)

¹⁹ The shareholders are part of sugar-alcohol groups including Copersucar, Cosan, Allicom and Crystalsev, São Martinho S.A., USJ – Açúcar e Álcool S.A., Santa Cruz S.A, Teaçú Armazém Gerais S.A., Viralcool Açúcar e Álcool Ltda., Usina Santa Fé S.A., Ferrari Agro indústria S.A., Usina Monte Alegre Ltda., and Agroindustrial Santa Juliana S.A.

4.8.3.2 Knowledge Spill-over

The private sector is the major investor and driver of innovations in biofuels in Brazil and in particular the large firms (IADB, 2007; Amaral, 2008). The dominant firms are in general developing more knowledge through research than weaker ones and also importing and adapting foreign technology, which is later spilled over to other firms. For example, Dedini develops new knowledge, which is later spilled over to other actors, through collaboration and labour rotation, as in the case of CSJ Metalúrgica, which recruits from Dedini (Sartori, 2008). However, spill-over also comes from the process whereby Dedini subcontracts assignments to CSJ Metalúrgica, and in this process they specify mechanical solutions and from this there is a knowledge spill-over. Dedini employs people from universities and sub-contracts research, and upgrades local human capital which is spread to other firms.

Another source is through spin-offs, one example being Technopulp Ltd that in 1974 spun out of the Indústrias Matarazzo, at the time one of Brazil's largest industrial conglomerates (Komar, 2007a). Another example is Biorigin, which spun out of the Zillo Lorenzetti group, one of Brazil's main groups in the sugarcane industry. This is a biotechnology company specialising in the production of natural ingredients for the food industry, for both humans and animals (Inovação Unicamp, 2006b).

Another form through which quasi hierarchies influence knowledge spill-over is that they can pressure suppliers to incorporate new practices; one such example here is COSAN, which induces suppliers of sugarcane to their mills to follow specific practices, in which new technology usage is diffused (Zylberstajn, 2006, COSAN, 2010).

4.8.3.3 Specialisation

In the early period there was mainly a process of conglomeration and build-up of in-house resources, and quasi hierarchy relations did not build up much of the specialisation and division of labour in this period. Large firms, and in particular sugar mills, offered all types of internal services to employees, such as housing, schooling, health care etc. (Dubeaux, 2007; Josenalda, 2007). There was some increased specialisation through the increased purchasing of equipment for production of ethanol. After deregulation, however, there are processes of mergers and acquisitions in which some firms are growing vertically and horizontally, but at the same

time they are abstaining from a number of activities, and one notable area is that there is a change in the employer-employee relation, towards a more professional than paternalistic relation; salaries are higher, but there is a decrease in additional services (Dubeaux, 2007; Josenalda, 2007). Likewise more technology is being bought from external sources, and some services and consultants are being used more frequently. For example, Caña Viallis which has contracts with 46 mills that have 15% of sugarcane lands; likewise, CTC has been transferred out of the co-operative of Copersucar (T. Andrade, 2008).

Mills are also influencing the purchasing of cane from external growers, but have an increasing interest in influencing the behaviour of suppliers; for example Cosan (2010) has set up a programme specifying the behaviour of suppliers. Other millers are leasing land from small farmers and operating it with their own crews (Zylberstajn, 2006).

4.8.3.4 User-Producer Learning

Related to the knowledge spill-over process, quasi hierarchies are important in user-producer learning, where dominant actors with good connections to national and international markets have good knowledge of competitive requirements, which is diffused to suppliers. In Piracicaba Dedini grew out of the relation to sugar mills. In Piracicaba it seems as if the existence of a metal-mechanical industry in the state and the demand for equipment from the sugar industry have benefited each other through the existence of complementarities that have driven the development of the local industry.

Dominant firms and especially mills serve as testing grounds for new and smaller firms that want to develop new technologies. An example is Smar Industrial Equipment, which is Brazil's main manufacturer of instruments for electronic control of industrial processes; they began in 1978 by building a conveyor belt for sugarcane milling for a plant close to their offices (Simões, 2006b). Another example is that B&S and JW, which design and build equipment for the sugar industry, have tested new technologies at the Santa Elisa Sugar Mill, located in their municipality of Sertãozinho, where they were allowed to use a pilot plant that the mill has discontinued (Simões, 2006b). Likewise the precision agriculture company Enalta has sold and tested its first implementations of tools for precision agriculture in two harvesters of a large multinational firm, located not far from their offices (Bueno, 2006).

In Piracicaba there are a number of large metal-mechanical firms that serve national and global markets of millers, such as Dedini, Sermatec, Mause, CSJ and NG. Minor companies supply these large firms, and piggyback on them to reach national and global markets (Mazzoldi, 2008; Calil, 2008).

4.8.3.5 Joint Action

Dominant firms are very influential in different networks, such as UNICA, APLA, Uniduto Logistics and Consecana, and as deliberative counterparts of state arrangements, such as the Pró-Álcool programme where Copersucar and CTC was important. Companies like Dedini, Copersucar and Cosan reoccur in most of these projects and initiatives. Without these leader firms there would be no programmes, as there would not be sufficient influence in the industry. These firms, if willing to participate, will also bring weaker parties with them into projects.

At the same time there is a danger when these dominant firms also get to dominate public policy, as there is a risk that there will be measures that prevent newcomers in favour of the incumbents. Before deregulation, there were many measures in place that seem to have benefited incumbents in the industry, and it is highly likely that the use of quasi hierarchy relations exerted influence to affect networks and state arrangements to protect their position (Storel, 2006, Gomez, 2007; Armijo and Kearney, 2008).

The dominant actors are still influential in networks and in dialogues with the governments. For example, FAPESP has set up a research programme in-house at Dedini (Inovação Unicamp, 2007). These are also influencing networks that lobby governments. However, no indication has been found that this is currently preventing newcomers in the industry. On the contrary, there seems to be a rise of new firms in all parts of the industry, with new services, new constellations operating mills, and foreign investment (Vian et al., 2005; Zylberstajn, 2006; T. Andrade, 2008). However, their strong position may cause a diversion of resources from other less influential industries to the sugar industry.

Furthermore, more dominant firms can establish collaborative projects with weaker firms, where larger firms can benefit from specialised niche products, and the weaker firm can piggyback on the more dominant firm to reach markets otherwise non-accessible; one such example is the DLG Automação Industrial, which benefits from collaboration with Smar Equipamentos

Industriais, both located in Sertãozinho (Komar, 2007b). Smar supported the start-up of the firm out of the bankruptcy of another firm. Smar's view is that the DLG product line complements their solutions and that DLGs products benefit Smar, as DLG has a high technical level. Smar in turn is a 30-year-old firm with subsidiaries in all continents, with exports to more than 60 countries, and it supplies several industrial sectors, especially the sugar & alcohol industry. They have automated hundreds of sugar and alcohol mills in Brazil and abroad, often using DLG parts.

4.8.4 State Arrangements

4.8.4.1 Intense Competition

Before the 1990s state arrangements were more dominant in the sugar cluster. The state operated more organisations, and regulated the economy more, whereas the IAA dominated most parts of relations in the sugar production process, setting prices and quotas and deciding who could set up new mills (Signorini et al., 2010). There was less competition (Martines-Filho, 2006; Roque de Oliveira, 2008). Brazil's former president, Fernando Henrique Cardoso (2006), describes in his memoirs how growth picked up substantially in Brazil in the 1970s, and was often referred to as an economic miracle, but this growth did not benefit any of the poor but only the established actors, who were the military government's power base. As the government controlled all unions, workers could not raise salaries, which fell relative to the high inflation. Also, government industry policies were mainly intended to further the interests of the established actors of the sector (Armijo and Kearney, 2008). The state supported incumbent interests, and made it harder for new actors to establish themselves, and also supported the sugar industry at the expense of other actors and technologies.

There has been anti-trust legislation from 1962, but the enforcement has been lax or non-existent for most all of the time. From 1994, with the introduction of law 8884, there was an increased emphasis on regulating competition to control mergers. The institution in charge, CADE, has not prevented many mergers, however, but rather focused on the behaviour of actors (Baer, 2008).

In the 1990s there was a move away from price and quota regulations (Martines-Filho, 2006; De Almeida et al., 2007) and in the beginning the main focus was on macroeconomic balances and increasing competition in

the economy, with some financing of research, but not so much on creating linkages between industry and universities (Meyer-Stamer, 1995). At the end of the 1990s and beginning in the 2000s, however, it moved towards keeping the macro economic framework, but also arranging finance, providing science and technology resources, creating linkages (such as cluster initiatives and technology roadmaps and science parks), supporting new firm start-ups, dealing with infrastructure, supporting exportation, and dealing with world trade arrangements (Brito and de Mello, 2006; Amaral, 2006; Santos, 2008).

There are still some subsidies to ethanol production and to consumers for buying flex-fuel cars (Armijo and Kearney, 2008). However, it diverts much focus and resources towards the incumbent sugar industry, which that can be at the expense of other industries, and possibly important innovative industries. Some argue that the sugar industry gets more attention than it deserves, as other industries are more important, such as soybeans in agriculture, or the automotive and mining industries (Zylberstajn, 2006).

There has also been a fear among some of the respondents that the current support will further strengthen market-oriented herd behaviour and lead to an over-investment in the industry and in particular in milling capacity, for which there are favourable government loans (Vian, 2006). There is a fear that in the last few years there has been a cyclical boom due to favourable global prices (for oil) and demand for sugar and ethanol, but these price levels may not remain, and there will be busts in the industry, as was the case in the 1970s and 1990s (Storel, 2006).

4.8.4.2 Knowledge Spill-over

State arrangements have enabled spill-over, by providing educational services and knowledge production at universities, e.g. ESALQ and research centres, such as Planalsucar, RIDESA and Pró-Álcool.

The state has also prevented spill-over, by regulations that previously made it harder for new firms to establish themselves, and protected incumbents by quota schemes and high degrees of regulations for new firm start-up. In general Brazilian industrial policies up to the 1990s were geared to supporting large firms, and even though there was deregulation in the 1990s, the policies of the time to strictly manage the macro economic framework led to high interest rates, which were very negative for new firm

start-up and firm growth (Machado Arroio, 2008). In recent years it has become easier to start businesses in Brazil, and a programme called SIMPLES was introduced in 2008 to simplify processes for small firms, but still many small firms remain in the informal sector (Machado Arroio, 2008). There are also indications that it is still relatively complicated compared to other countries, and Brazil comes 129th in the World Bank ranking of how easy it is to operate a business (World Bank, 2010).

At the same time there are state arrangements supporting new firm start-up. One important example of this is that SEBRAE has many activities geared towards the training of entrepreneurs and helping with micro financing to entrepreneurs (Ribeiro, 2006). They are also operating incubators, and in Piracicaba there has been one connected to ESALQ since 2005 (Barbosa, 2006). Furthermore, the state government of São Paulo supports technology spill-over through the FAPESP PIPE programme. This has financed over 700 projects of technology spin-off and technology-based business development, including industry university collaboration. Examples mentioned in this thesis are Enalta (Bueno, 2006), BUG (Da Silveira, 2008), PHB (Molinari, 2006) and Technopulp (Komar, 2007a).

State arrangements have also created places for supporting start-ups and linkages such as incubators and science parks. In Piracicaba there is a process of opening up a science park; it was supposed to open in 2008 but has been delayed until 2010 (Izique, 2007). Firms like Caterpillar, Novozymes have already committed to locate in the science park. There is an incubator in Piracicaba that was started in 2006 (Barbosa, 2006). It has two employees and is financed by SEBRAE, ESALQ, the Prefecture and the S&T secretariat of state of São Paulo; all firms located in the incubator are related to environment and agribusiness.

4.8.4.3 Specialisation

State arrangements are enabling specialisation, by facilities for new research, through education, vocational training, from procurement practices for ethanol and legislation making certain behaviour mandatory. Activities are carried out by federal, state and local governments. There have also been joint activities by state arrangements and private networks creating the knowledge and technology behind the growth of the Brazilian sugar industry, with new sugarcane varieties, diversification in output from sugar and improved processes.

Technology development and specialisation began in the 1970s with CTC, IAC, Planalsucar and the Pró-Álcool programme. There had been some prior research activity in Campinas IAC, but not with a broad impact. These units created new technology and gave incentives to innovations and economic upgrading of the sugar industry. Policymakers used different tools to achieve their objectives, such as increasing demand for ethanol by making it mandatory to mix a certain percentage of all petrol with ethanol, to make it mandatory for filling stations to provide pure ethanol, to provide R&D support to develop the technology of ethanol cars (Martines-Filho et al., 2006; De Almeida et al., 2007). Pró-Álcool was a national programme but it had great repercussions for the clusters, and it also originated from actors in the cluster around Piracicaba.

At the same time there were taxation policies in place with high cumulative effects from state and federal taxes that punished collaboration among firms, and stimulated in-house activities that made firms spread research over a broad spectrum of activities, instead of specialising and collaborating (Meyer-Stamer, 1995).

In general in Brazilian R&D funding the state is the major investor (Brito Cruz and de Mello, 2006), but in the sugar industry it is the private sector, with almost 80% (IADB, 2007; Amaral, 2008). With regard to the development of Brazil, it is frequently argued that there is a need for more and better skilled labour and also better connection between university and firms in formulating research agendas (Meyer-Stamer, 1995). It is likely that the sugar sector is one of the areas in Brazil that performs best with regard to connections between university and industry, despite Pintec indications of low direct collaboration rates for innovation (IBGE, 2010). In general in Brazil, the previous policies of import substitution have often led local firms to import foreign technology, adapting it slightly to local markets with little interaction with industry. However, in the case of ethanol as automotive fuel, genuinely new technology was developed (Meyer-Stamer, 1995).

In São Paulo it is not only the federal government that is an important actor, but also the state of São Paulo; the funding of R&D in the state is to two thirds public funding and it is Latin America's second largest investor, ahead of Mexico and Argentina (Brito Cruz and de Mello, 2006).

Since 1961 the state of São Paulo has had FAPESP, which supports the development of technology; among other things, they were behind the

projects to map the genome of the sugarcane, from which a number of new firms have been started and many new sugarcane varieties are also being developed. FAPESP has many programmes to link industry, universities and institutes, such as the PIPE programme for small businesses (mentioned above under Knowledge Spill-over) and the PITE programme to stimulate partnerships between universities and industry. For example, FAPESP is one financer of the development of Dedini's hydrolysis technology. Together with Dedini, FAPESP has also initiated a specific research programme in sugarcane technology of BRL 100 million to identify and address strategic issues in 2007–2011 (De Carvalho Varrichio and Queiroz, 2010). FAPESP also has the programme for Research on Bio-energy (BIOEN), which aims to stimulate academic and industrial laboratories to advance and apply knowledge in fields related to bio-ethanol production (De Carvalho Varrichio and Queiroz, 2010). There are five areas of interest: i) Biomass research, ii) Ethanol technologies research, iii) Alcohol chemistry and bio-refineries, iv) Engines, and v) Impacts on social, economic and environmental areas, land use, intellectual property associated with the biofuel industry.

The São Paulo State Government also sponsors research through the Agency for Agribusiness Technology of São Paulo (APTA), which consists of six research institutes and 15 regional centres in a decentralised network, led by the Centre for Advanced Technological Research on Sugarcane Agribusiness in Ribeirão Preto. They carry out research on sugarcane cultivation, in interaction between institutes, sugarcane firms, sugarcane suppliers, universities and Embrapa, UNICAMP, UNESP and the Institute for Technological Research (IPT). IPT is a public company developing industrial fermentation and providing services of biochemical laboratory analysis of alcohol. The programme operates in several areas of knowledge such as breeding, biological control, techniques of cultivation and management, economics, sociology, statistics and agro-meteorology (Fronzaglia and Martins, 2006).

In São Paulo there are numerous public institutes or knowledge networks in place today that create new knowledge and further specialisation of the industry, such as RIDESA (the continuation of the Planalsucar network), which has developed important new sugarcane varieties. The university in São Carlos, in the state of São Paulo and its Departamento de Biologia Vegetal have been leaders in this process. The Agronomic Institute of

Campinas (IAC) is responsible for research and development of new varieties. It is in charge of genetic enhancement, physiology, climatology, phyto-technology, etc. The Agricultural Economics Institute (IEA) carries out socio-economic studies, policy research, and manages the State's agricultural statistics. The Biological Institute (IB) does research on pests and diseases, provides education and assistance and issues certificates with respect to pest control and diseases (Ueck, 2007). In 2009 the Science and Technology Ministry (MCT) funded the Ethanol Science and Technology Centre (CTBE), which is located in Campinas near Unicamp. The focus is on basic and applied research, and in particular on second-generation bio-ethanol hydrolysis processes. There are also activities related to low-impact mechanisation of harvesting and plantation, sustainability and virtual biorefineries (De Carvalho Varrichio and Queiroz, 2010). The Agriculture College Luiz de Queiroz (ESALQ), which is located in Piracicaba. The Centre for Nuclear Energy in Agriculture (CENA), the School of Engineering of Piracicaba (EEP), the Methodist University (UNIMEP) and are also located in the city.

There are a number of programmes from local, state and federal levels for education and vocational training and also with co-ordination with private actors. Piracicaba municipality, together with APLA, has been a driving force behind the establishment of the FATEC (Faculdade de Tecnologia), a technical college with courses in technical and managerial competences needed for the sugar industry, with a focus on bio-energy (Santos, 2008). The FATEC programmes are influenced by demands of industry and local municipalities, which also participate in designing the programmes (Portal do Governo do Estado de São Paulo, 2010b). In Piracicaba there will also be a CIFET, which is a federal technical school with two-year educational programmes. Currently there is an ETEC high school that provides technical training. In the ETECs (Escolas Técnicas) secondary education level courses and some professional courses are provided. The curriculum is co-ordinated with local labour market demands and courses are designed together with local municipalities and industry. In Piracicaba there are courses in sugar and ethanol production (Portal do Governo do Estado de São Paulo, 2010b). When the science park is in place, these schools will be located there (Santos, 2008).

Piracicaba municipality has also undertaken activities to retrain local unemployed in order to address challenges of lack of skilled employees, but

with mixed results (Santos, 2008). There have also been recruitment campaigns to attract labour from the North East. The problem with skilled labour will increase in a not too distant future, when firms will increase mechanisation. According to Santos (2008) who is leading the work at the state of São Paulo's development office, at least 200,000 of the seasonal harvest labour presently employed will not be needed in the near future, and of these 80,000 can be employed as mechanics and technicians for the new machinery, but there is a need for retraining. However, of these 200,000 people many are illiterate and will be hard to retrain. There are already state programmes in place for qualification of employees at sugar mills, capacitating people to become drivers, tractor operator, harvesters and operators of heavy machinery. The programmes have been carried out in 2009 and 2010 and claim to have saved 300 people from unemployment (Portal do Governo do Estado de São Paulo, 2010a).

4.8.4.4 User-producer learning

Through the Pró-Álcool programme and later through legislation that makes it mandatory to mix petrol with ethanol and for filling stations to carry pure ethanol, state arrangements have fostered innovation and economic upgrading of the sugar industry by inducing user-producer processes (Martines-Filho et al., 2006; De Almeida et al., 2007).

Between 1975 and 1985 the focus was on raising productivity (one outcome was that fermentation productivity rose more than 130%), from 1980 onwards the focus was on conversion efficiency and outcomes from fermentation; after 1985 new tools for agro-industry management were in focus (De Carvalho Varrichio and Queiroz, 2010). The growing demand from the São Paulo sugar industry induced Dedini to alter its technological profile. It increased its activities in sugar equipment. Dedini was very active in the 1980s, but declined seriously in the 1990s after Pró-Álcool was closed, but as the market has picked up again in the beginning of the 2000s and so has the patenting activity (Tosi et al., 2008).

The government is also implementing new legislation in order to address environmental problems stemming from the growing sugar industry, such as land degradation, deforestation, threats to biodiversity and pollution. Problems have arisen due to neglect of implementation of best management practices, ineffective legislation and control. In São Paulo processes have improved substantially during the last three decades, but there is still a need

for improvement (Fischer et al., 2008). There is also legislation being implemented to prohibit the burning of cane. This legislation creates challenges, but it also stimulates innovation and upgrading activity as many firms are beginning to mechanise harvesting. There are also favourable loans for mechanisation (Cortez, 2007 and Evangelista, 2007). Another reason for mechanisation is to raise productivity. For example, sugarcane harvesting is only mechanised to around 35%, whereas soybean is 100% (Bueno, 2006). Mechanisation is not without challenges, though, and there are needs to improve the present equipment. Mechanised harvesting causes losses, as the cane cannot be cut close enough to the ground, where most of the sugar content of the cane is gathered. There is also loss from cane being dropped in fields (in many places up to 10% is lost). Furthermore, harvesters pack the soil so that there are challenges for future harvests. As a response to this a number of research projects have been initiated to improve harvesters. The above challenges of mechanisation were brought up in the deliberative process initiated by FAPESP to develop guidelines for designing public policies and creating a technology roadmap for the sugar industry, involving industry, researcher and government. The project deals not only with mechanisation, but also with cane collection, fermentation and hydrolysis (Simões, 2006c).

4.8.4.5 Joint Action

The ethanol industry has the highest support, and President Lula Da Silva, despite previous grievances with the industry, has described the ethanol producers as national and world heroes (International Herald Tribune, 2007). There have been numerous policies, initiatives and activities on local, state and federal levels, geared towards clusters, directly such as the efforts with APLs, but also towards the economic framework, and horizontal policies towards the industry, such as R&D programmes like RIDESA.

The state addressed the inertia of the industry in the 1960s through the Planalsucar and Pró-Álcool programmes, which can be seen as system level innovation. It included activities of restructuring by closing down unproductive mills, and by stimulating mergers and acquisitions among others. It also initiated programmes to develop new cane varieties (Ueki, 2007). The Pró-Álcool programme worked on many levels in order to create a system for ethanol-fuelled cars (Goldemberg et al., 2003; Gomez, 2007) and other derivatives such as source for plastics (Molinari, 2006).

There are presently a number of state arrangements in place that to address issues that could create problems of lock-in and congestion. There are a number of basic research programmes, education and retraining of labour, as well as projects to address infrastructure challenges. These activities are carried out in specific policy areas, but there are also some specific cluster programmes, such as the APL (Arranjos Produtivos Locais, local productivity arrangements) programme from SEBRAE, which supports SME business networks (Goulart de Miranda, 2006). This programme is one of the key factors behind the APLA in Piracicaba.

The APLA seeks, through collaborative efforts, to address topics related to all of the sugar value chain, in order to lower production costs and raise firm competitiveness (Ribeiro, 2006). For APLA a key challenge is logistics and infrastructure. There have been visionary discussions regarding the opening up of the river to be able to transport to Argentina and out to the Atlantic. Other plans include reopening the railway to Piracicaba from São Paulo (Santos, 2006). The government has helped out to some extent by improving the road system, but it does not seem to be sufficient at the moment. State arrangements are supporting APLA through the Brazilian Trade and Investment Promotion Agency (APEX), which finances export trips and group visits to trade fairs. There are also challenges with lack of skilled labour. APLA, together with the state government, has addressed this by different educational and vocational training programmes, such as FATEC, CIFET, ETEC, and collaboration with private sector networks and programmes like SENAI and SESI.

In Brazil APL projects are normally geared towards networks of small firms, with the purpose of strengthening their collective competitiveness, by raising capabilities and identifying opportunities for collective action (de Souza Freies, 2006). For the head office of SEBRAE São Paulo, the APLA efforts are concentrated on small firms that supply Dedini in the intersection of the ethanol and metal-mechanical industry, and not on the entire ethanol chain (Cavaleri, 2006, 2008). SEBRAE's activities with the Dedini suppliers involve gathering the small firms to identify needs and opportunities and to jointly create a plan for how to address this and to provide training, with the help of market research, exporting missions and certification schemes (Estacio, 2008). At the same time APLA as an organisation is including all of the value chain.

The State of São Paulo has invested in a number of cluster initiatives, both in collaboration with SEBRAE and together with the Inter American Development Bank (BID) and FIESP and CIESP. These are not geared to the sugar industry, but knowledge is transferred between the programmes as the state regional development office has created a network for cluster initiative learning that diffuses knowledge between the cluster initiatives and supports them in their work.

4.8.5 Summary of São Paulo

São Paulo benefits from good natural conditions for growing sugarcane, and there is a large domestic market that purchases sugar and ethanol so that regular incomes are generated. There is a thick institutional weave with complementary assets in place, in the form of firms from all parts of the value network, advanced research institutes and supportive state agencies.

At the beginning of the 1970s Brazil was not very advanced technology-wise, but after that the sector has grown and the technological levels as well. From 1970 to 1990 state arrangements stimulated innovation and upgrading, by arrangements that created specialisation and new technology by public research institutes and funding of research in private networks like CTC. Through the co-ordination of the Pró-Álcool programme in Brazil there was an establishment of a system of ethanol-driven cars. There was procurement of ethanol and a system of subsidies making ethanol more advantageous for consumers, which created a stable market for development of technology to create ethanol as an automotive fuel. To enable this there was also R&D funding for the automotive industry and processing equipment industry, and legal requirements enabling the technology system by making it mandatory for filling stations to carry ethanol and by granting subsidies to consumers (Goldemberg et al., 2003; Martinez-Filho, 2006; De Almeida et al., 2007). There was also funding for other types of diversification such as making plastics from sugarcane ethanol (Inovação Unicamp, 2006b).

At the same time, network arrangements like CTC and dominant firms like DEDINI, COSAN and Copersucar were important for innovation in the sugar industry. They participated in developing new cane varieties and sugarcane technologies to increase yields of growing sugarcane, and in the development of industrial processes to increase yield in sugar and ethanol processes (Tosi Furtado et al., 2008). Local user-producer relations between

mills and suppliers of metal-mechanical equipment, as well as between small-scale suppliers to large metal-mechanical firms were and are important in developing technology in São Paulo.

The networks in the cluster in Piracicaba were influential in the launch of the Pró-Álcool programme (T. Andrade, 2008). The arrangements in the era led to the development of new technology, but fewer new actors, and it protected the incumbent actors of the industry. Intense competition was of less importance from 1970 to 1990, which prevented innovation in many other sectors. In the sugar sector it protected incumbents, but also created innovation-enhancing networks with high involvement of relations between industry, research and government activities. Innovations and long-term networks were generated which were utilised in multiple innovations, ethanol, bioplastics and rapid hydrolysis (Velho and Velho, 2006; Inovação Unicamp, 2007)

In the last two decades the role of the state has diminished and the drivers of the sugar industry and cluster externalities seem to be more market-based (Vian et al., 2005; Inovação Unicamp, 2007), even though state arrangements, networks and quasi hierarchies remain very important. Federal policies were very important before the 1990s and remain very important. State arrangements have however changed in form, with less direct intervention, through regulation of prices and quotas, but there is more a role of financing upgrading and research, facilitating processes, and networks and private actors are more important, not only for production, but in deliberating policies and creating innovations. Before the 1990s state arrangements were dominant, influencing how the other arrangements were operating, such as reduced effects of market arrangements. Since 1990 arrangements have been more equalised and market arrangements have become much more frequent, and as a result state arrangements have also been influenced by the more market-oriented order, and funding for firms has to an increased degree begun to be provided in open competition, rather than given to picked winners.

Since deregulation the pressures to innovate have become more important. This has led to an increased pressure to innovate and increase productivity, as there are no protected quotas for actors to survive upon any longer, so they are pressured to innovate (Vian et al., 2005). Non-productive and uncompetitive firms were cleaned out in the 1990s and early 2000s during

periods of crisis, and many firms have relocated resources in more productive areas, and abandoned land that has become uncompetitive (Cortez, 2007; Evangelista, 2007). Due to globalisation competition has increased, as have opportunities. High oil prices and the breakthrough of the flex-fuel technology have created strong domestic markets. There is also a strong world market demand for technology, sugar and ethanol that is currently very important for the development of the industry (Zylberstajn, 2006; Amaral, 2008). However, there are many local relations that remain important and are conducive to innovation.

The presence of market conditions that generate signals and pressures to innovate, together with arrangements for collaboration and research facilities, has created conducive conditions for innovation in the cluster. There are incentives to develop new technology, both carrots in the shape of a high demand and state subsidies for innovation activities, and sticks in the shape of risk of going bankrupt if innovations are not implemented. At the end of the 1990s a large number of unproductive firms went bankrupt. However, a number of new firms have emerged, small suppliers that have grown organically, piggybacking on large firms in quasi hierarchy relations, new science- and technology-based firms often supported by state funding or through relations with large firms (Inovação Unicamp, 2006b; Simões, 2006b; Komar, 2007a, 2007b). These firms provide new types of products and services for the industry, creating greater division of labour and increased specialisation.

There are other also other types of market-based pressures. The sugar industry has had a bad reputation and is repositioning itself as an environment-friendly industry (Amaral, 2006, 2008; Piros Kovacs, 2007). As there is a strong interest in global markets, the industry is quite responsive to international concerns for sustainability issues, as well as issues regarding workers' rights. Many firms are undergoing corporate social responsibility and certification programmes in order to strengthen their image and meet these international concerns. This is due to international and local market signals, and also local ones.

The respondents and the empirical literature do not indicate that it is personal rivalry among entrepreneurs for social standing that drives local rivalry in the cluster. If there is any type of socially motivated rivalry it seems to be more oriented against actors from the North East. On the other hand,

competition does not seem to be blind and geared broadly, but there appears to be knowledge about who the competitors of a firm are (Boari et al., 2003) and the respondents had opinions about the activities of their competitors (Almeida, 2007; Nieto, 2007; Santos, 2006; Sartori, 2008; T. Andrade, 2008). At the same time, respondents also to a greater extent discussed possibilities for collaboration, which could be due to the growing market opportunities that few of the firms could grab by themselves (Sartori, 2008; Santos, 2006, 2008).

Networks are also becoming more visible and also more geared to deliberating common problems and creating innovations, rather than lobbying government for protection. Networks were important for developing new innovations, such as the arrangements around the development of the Rapid Hydrolysis that involves Dedini, CTC, Copersucar and FAPESP (Inovação Unicamp, 2007a). The networks are also conducive to deliberating activities to address public-good issues. Some activities that were previously carried out by the state as price negotiations are now being carried out in network arrangements, Consecana. Joint problems of infrastructure are also being addressed, for example, by UNIDUTO and APLA. The APLA project is very interesting, but it remains to be seen whether all the visions drawn up will materialise; if it will lead to the generation of new technology, or if it will remain more of a social innovation. Still the organisation has generated advantages for its participants, in increased order sharing, generation of new orders, and deliberation of common needs.

The respondents and the literature do not indicate that it is community-based relations outside of the professional relations that underpin collaboration in the cluster, but rather it is long-term professional relations. These relations exist in formal and informal networks, though (Amaral, 2006; Vian, 2006; T. Andrade, 2008; Sartori, 2008).

Furthermore, as decisions are made in the market, it becomes less relevant for vested interests to lobby government for advantages, as it is no longer decided by the state. However, world market conditions are very positive and the industry is receiving much support, through procurement practices and R&D funding. The situation is such that the sugar industry in São Paulo has greater opportunities than anyone can grab for themselves, and there are probably greater gains for any actor by further expanding the

markets, therefore it is not in the interest of any actor in São Paulo to return to old-time interventionist measures (Cordeiro, 2006; Santos, 2006; T. Andrade, 2008; Sartori, 2008).

Quasi hierarchies seem to be very important in Piracicaba. The large firms and organisations are the ones that are leading in the different joint initiatives and networks. COSAN, Copersucar and Dedini are very influential actors in most of the network arrangements identified (Amaral, 2006; Vian, 2006; T. Andrade, 2008). They also develop new technologies that are spread to other actors, either by imposing certain behaviours in order to supply to them, like COSAN with sugarcane providers, through informal networks, through requirements in the development of technology like Dedini with small-scale suppliers, and through spin-offs.

The importance of intellectual properties and innovations seems to increase by the year; technology-based firms are increasing, the numbers of researchers and patents also. São Paulo and in particular Piracicaba seem to benefit greatly from this, as Piracicaba has a strong concentration of capabilities in sugar technology and there is a great international interest in locating close by to access the local knowledge base. The local presence of strong human capital can be attributed to network and state arrangements that provide education and vocational training schemes. Furthermore, advanced employers are also developing employees through learning by doing, and here the dominant firms in quasi hierarchies are important.

The actual production of sugar and ethanol around Piracicaba will probably decrease in the future, as the terrain is too hilly, and with the altering of legislation about burning fields, there will probably be less land available for sugarcane production (Castelar, 2008; Calil, 2008; T. Andrade, 2008). There are also indications of congestion with regard to limits in infrastructure and lack of skilled labour that will be required for increased mechanisation (Santos, 2008). There are also fears that the presently market-oriented arrangements are not diverting enough resources for long-term research, as there is much focus on solving challenges in the present (Inovação Unicamp, 2006a) and that state investment in research and innovation is focusing too much on incremental engineering projects, rather than more radical and scientifically based projects (Simões, 2007a).

Table 26 gives a summary of how institutional arrangements have influenced cluster externalities that can have an impact on innovation in São Paulo.

Table 26: Summary of institutional arrangements and externalities in São Paulo

	Intense competition	Knowledge spill-over	Specialisation	Demand	Joint action
Market	Market arrangements and competition have increased, with more innovation. No indications of personal rivalry Fear that market-driven actors under-invest in basic research, infrastructure and education of skilled labour	Labour rotation. Many new start-ups, benefiting from complementary firms	Increased specialisation and division of labour among firms and research institutes New external investors establish to access skills, but also bring new knowledge	Local relations have been important for creating resources for innovations and input for resource allocation.	No indications
Network	Incumbent actors, together with state (IAA), prevented newcomers in the sugar industry. Currently not preventing, specific actors or technologies, but gaining resources at the expense of other industries.	Spill-over from informal networks, and formal ones, between researchers and industry, and between industry actors, CTC, APLA, ORPLANA, and UNICA. Firm start-up, benefiting from networks of established actors. Spun out of technologies from networks.	Networks provide specialised services and carry out research, e.g. ORPLANA, CTC, SESI, and SENAI.	Professional networks behind the development of new technology, such as the collaboration between Dedini, CTC, and Copersucar for hydrolysis. Particularly important for more insecure processes.	Addressing problems of inertia and lock-in, e.g. creating new technologies in CTC and the lobbying for Pró-Alcool; for infrastructure, e.g. Uniduto. Carrying out price negotiations in Consecana.
Quasi hierarchy	Incumbent influential actors, through state arrangements used to prevent newcomers in the sugar industry. Now possibly getting advantages compared to other less influential industries.	Dominant firms develop and import new technology, diffused through requirements on suppliers. Also from spin-offs from dominant firms. Through informal networks.	Industry was consolidating 1970–1990. Later more diversification, as dominant firms outsource more. Still growth of a number of firms, in processes of vertical and horizontal mergers.	Knowledge diffusion as suppliers pick up practices from dominant firms. Dominant firms serve as testing grounds Small firms piggyback on dominant ones to reach markets.	Influential in networks, due to resources and power, e.g. APLA, UNIDUTO. Small firms can provide large firms with specialised innovations not large enough to be developed within dominant firm that can complement offering of dominant firm.
State	Previously restricted competition, now monitoring behaviour of actors. Danger of stimulating over-capacity.	Developing new knowledge, by organisations, networks and funding of private actors. Diffused through education and formal and informal networks. Support to start-ups, through SEBRAE, FAPESP, and PIPE. Previously State arrangements used to prevent start-ups. Stimulate linkages, e.g. APLA	Support to specialisation of labour through education and vocational training. Support to specialisation of firms through development of new knowledge in research organisations and through financing of innovation and upgrading in firms. Provides specialised services conducive to industry, e.g. standardisation	The state fosters user-producer learning through public procurement of ethanol and through legislation that makes certain types of behaviour mandatory.	Has mobilised industry and research centres to develop technologies, and system level innovation, to break industrial inertia. Addressing lock-in, by investments in basic science, education and retraining, also in infrastructure. Deliberative projects like APLA, technology roadmaps, and financing schemes that stimulate collaboration among actors.

4.9 North East Institutional Arrangements

4.9.1 Market Arrangements

4.9.1.1 Intense Competition

Before the 1990s the sugar industry was strictly regulated, and market arrangements played a minor role in the North East. In the North East the cluster has been less diversified; it is dominated by sugar mills and providers of cane, whereas there are fewer suppliers of services and machinery and equipment (Neto, 2007; Storel, 2006).

Since 1990, there has been increased competition due to market arrangements that have opened up markets and removed protection for the North East. The number of competitors now includes non-local actors, from other parts of the country and foreign investors. The increased competition has created great pressures on the sugar industry in the North East, and many mills have been closed. In many places of the North East natural conditions are such that sugar and ethanol cannot be produced competitively compared to the centres south. However, in some areas it is possible (Almeida, 2007; T. Andrade, 2008). The ones with high productivity levels remain in the region. At the same time, firms in the North East have sought different kinds of differentiation strategies in order to respond to the challenge. Many firms are investing outside of the state and moving capital, finance and machinery from Pernambuco to other states; e.g. Lira and Coruripe are moving and expanding to Minas Gerais and São Paulo (A. Andrade, 2007). Another movement is to seek alternatives for innovation in the production process and differentiation in product output. The firms that were interviewed in the North East nevertheless had a positive outlook on the future, a view shared by the respondents in SEBRAE's (2007) survey of the future of the local economy. Usina Coruripe was already highly productive and had figures equal to the better ones in São Paulo (see Appendix 6).

The respondent from Grupo JB, Neto (2010), described their view of the increased competition after the reforms of the 1990s as follows: *“Every market you have competition, but a healthy competition. The market is very big and everyone can play. All competition challenges you to innovate both in the industry to extract more ethanol and sugar and in the field to produce more and better raw (sugarcane). We have always to work on costs reduction, so in this*

way we become more competitive. I think that today we are competing with the Southwest region, because they have a lower cost. They have higher agricultural productivity and industrial efficiency.”

This also reflects that no evidence of personal rivalry for social standing between the mills in the North East was found, or comparison due to transparent circumstances. The respondents referred more to competition with the Centre South or foreign countries (Almeida, 2007; Evangelista, 2007; Cortez, 2007; Neto, 2007, 2010). At the same time, it seemed as if the respondents were aware of whom their competitors were.

4.9.1.2. Knowledge Spill-over

I have found little indication of market arrangements affecting knowledge spill-over with an impact on innovation; if so there is a potential loss of labour moving to the Centre South (A. Andrade, 2007). There have been few start-ups in the sector and modest local labour rotation (Dubeaux, 2007).

4.9.1.3 Specialisation

The competition is driving the firms to specialise and innovate, some examples are the production of carbon dioxide, methanol gas, and electricity from sugarcane by products and in process innovations through irrigation and increased mechanisation; experiments with new cane varieties have reached levels of 250 tons/ha (Almeida, 2007). Still, some argue that the firms in the North East are not exploring these new possibilities sufficiently, such as the research director of CTC (T. Andrade, 2008).

Grupo JB, which is located in the hilly parts of Pernambuco, has not explored the opportunities with process upgrading to the same extent as Usina Coruripe. When they began they were a pure distillery, but now they have diversified. The emphasis has been on finding new market segments and products, and they are also diversifying by establishing plants in other parts of Brazil. They supply Cachaça to Pitú, one of Brazil's most famous brands, but they also produce ethanol for automotive fuel purposes and technical alcohol. Moving beyond alcohol, they have started production of sugar, crystallised white sugar, brown sugar and industrial sugar. They produce carbon dioxide, which is sold to the local soda industry, and they are planning to develop methane gas from vinasse. They have started to

generate electricity from bagasse, which is sold to the electricity grid, and they participate in Carbon Emission Schemes (Neto, 2007).

4.9.1.4 User-Producer Learning

There are some examples of the role of specialised local demand and the role of user-producer interaction, such as Implanor's machinery. Implanor is the only machine industry originating from the North East and it produces a sugarcane collector that works better in hilly terrain, which is the special conditions of the North East (A. Andrade, 2007).

The sugar industry, with its origins in using slave labour, has a long history of bad treatment of labour and a bad reputation among Brazilians. Many firms are repositioning themselves as bio-energy firms, and in this process they want their image to be one of sustainable and environment-friendly energy companies, and non-sustainable and labour-unfriendly practices would distort this image (Goulart de Miranda, 2007). Usina Coruripe, for example, has begun to replant rain forest on its land on the coast of Alagoas. The rainforest that used to exist there has previously been almost eradicated. Furthermore, the Usina participates in programmes to develop business and employment opportunities for locals (Almeida, 2007). The drive comes both from local pressures and from international fears of mistreatment of labour and destruction of rain forest to produce ethanol. This is especially important for the North East and exports large shares of its production. Many firms are spurred to take steps for certification by ISO, corporate social responsibility and compliance with Agenda 21. The Swedish biofuel company SEKAB, together with Brazilian counterparts, has developed a certification scheme (A. Andrade, 2007; Amaral, 2008).

4.9.1.5 Joint Action

I have not found any indications of market arrangements affecting joint action.

4.9.2 Network Arrangements

4.9.2.1 Intense Competition

Network arrangements have strengthened vested interests to prevent competition in the North East, rather than supporting competition. There

are activities on the part of the sugar industry associations, lobbying for protection of the industry (Evangelista, 2007; Cortez, 2007).

The Pró-Álcool programme and protective measures from IAA shielded the industry in the North East to allow it to grow. The industry did grow, but many respondents have indicated that in the North East, not so many new technologies and varieties were developed or deployed as in the Centre South (Simões Neto, 2007). In combination with unfavourable natural conditions, it developed an industry that in many regards was not competitive. The protection did not create space to re-innovate firms, but sustained non-competitive practices. The networks' influence on state arrangements kept this system in place (T. Andrade, 2008).

Still there is lobbying for different measures of support, such as procurement rates for ethanol, subsidies for flex-fuel cars and for lobbying of international trade schemes (Armijo and Kearney, 2008); and the sugar growers' association of the North East was preparing a lobbying campaign to make it mandatory for sugar mills to buy 40% of their sugarcane from independent growers (Moraes de Andrade Lima, 2006). The North East is also receiving subsidies, in the form of the Brazilian export quota to the US (Evangelista, 2007). The growers in the North East are also receiving a subsidy of BRL 5.00 per metric ton in order to balance the difference in cost of production between the Centre South and the North East (USDA, 2010).

There has also been an agreement from community concerns to protect labour and to avoid mechanisation between the trade unions and the employer's organisation, in areas where it would be possible to restructure through mechanisation, as the region has already suffered much loss of jobs in the sugar industry. Mechanisation is opposed by labour unions as work as cane cutter is highly valued by the labour union, and the firms accept that standpoint so far (De Santana, 2007). Estimations are that one harvester will replace around 15 (Almeida, 2007) to 80 cane cutters (Moraes de Andrade, 2007). Currently there is little mechanisation, approximately 30%, and this is mainly in collecting cane rather than cutting it (A. Andrade, 2007). However, with the implementation of the new legislation to prevent the burning of cane for environmental reasons, as well as increased competitive pressure, it is likely that most firms that have the possibilities will mechanise (Almeida, 2007).

There will be a need for re-education of labour, partly in order to manage unemployment, but there will also be a need for more skilled labour, which can become addressed by networks from millers and public training (A. Andrade, 2007; Cortez, 2007; Almeida, 2007).

4.9.2.2 Knowledge Spill-over

There is knowledge sharing between firms in official networks like trade associations; the Associação dos Fornecedores de Cana de Pernambuco (AFCP), which organises the small sugarcane growers, provides members with a number of services to diffuse best practices among members (Moraes de Andrade, 2007), and the same goes for the Syndicates of the Sugar and Ethanol Industry (Sindaçúcar) in Alagoas and Pernambuco (Evangelista, 2007; Cortez, 2007).

There are also networks between firms and universities and research institutes; for example, in the Coruripe mill, CTC and local universities are carrying out experiments and local university employees have helped in developing and adapting technology to the needs of Coruripe (Almeida, 2007).

There are also informal networks between millers, in which best practices and information about new technology have been shared. Since 1990, however, there seems to be less openness, and some indicate that the deregulation, at least in the North East, has led to less willingness to share knowledge with others. For example, Grupo JB has installed machinery to extract carbon dioxide from the production process; this machinery they keep to themselves and do not demonstrate to competitors, as not so many firms have implemented it yet (Neto, 2007). Likewise, the Pintec surveys (IBGE, 2002, 2010) indicate that collaboration is not regarded as highly important for innovation and that it is falling; at the same time, external sources are important for innovation, but not formal collaboration.

4.9.2.3 Specialisation

Before the 1990s there was more mainstreaming than specialisation and division of labour; since 1990 there has been more specialisation, but it is less due to network arrangements than market arrangements. There is some specialisation in the form of specific services from trade associations, such as AFCP and Sindaçúcar. Sindaçúcar is diffusing knowledge through seminars,

and promotion of different kinds of best practices (Evangelista, 2007; Cortez, 2007). AFCP organises the small sugarcane growers and provides its members with a number of services, such as technical services, insurance and some credits, legal and technical matters, social assistance, keeping track of biological control. They have three laboratories that are financed by the mills and the small growers (Morais de Andrade, 2007). AFCP also works together with RIDESA to develop new cane varieties. They have also carried out diversification programmes through which they have tried to educate farmers to grow sweet potato and cassava. However, the farmers have remained cool towards these crops.

4.9.2.4 User-Producer Learning

There are networks between firms and suppliers. However, the industry is not as diversified in the North East as in the Centre South, even though it is increasing somewhat. The firms allow suppliers to test and develop technology in their locations, Usina Coruripe was working together with Caterpillar (albeit the unit from Piracicaba), but there are fewer local firms to interact with. There is also collaboration between firms and universities and research institutes, as in Usina Coruripe where CTC are carrying out tests, and also with the local university, UFAL (Almeida, 2007).

4.9.2.5 Joint Action

When first asked, most actors claimed that collaboration in the North East was rather limited, which is also supported by Pintec data (IBGE, 2002, 2010). There were however some instances, such as the informal meetings between millers (Neto, 2007), different business organisations (Evangelista, 2007; Cortez, 2007), and university/industry collaborations (Almeida, 2007), such as RIDESA units in the Usina Coruripe (Simões Neto, 2007). There is no cluster initiative (like APLA) that incorporates all actors in order to formulate and address the common issues jointly in the North East, but there are some small cluster initiatives launched by SEBRAE, for tourism and for handicraft of sugar residuals (Wanderley, 2007). There are also a number of networks and associations in place, such as business associations, Sindaçúcar and AFCP, which are important for knowledge diffusion and the spread of new technologies and business practices, as well as for deliberating common issues (Evangelista, 2007; Cortez, 2007; Morais de Andrade, 2007).

AFCP handles price negotiations with Sindaçúcar, in the joint programme of Consecana. Consecana evaluates the sugar content of sugarcane and what prices ought to be paid for sugar to the producers. Consecana consists of representatives of mills and independent growers. This system provides incentives for growers to grow cane with high degrees of sugar content, and to get good prices for this (Morais de Andrade, 2007).

Through Sindaçúcar (the Union of Sugar and Alcohol Producers), millers are addressing joint challenges, such as lock-in problems with infrastructure. Sindaçúcar organises the sugar mills in Pernambuco. It provides market analysis and promotes environmentally sustainable production processes within the industry. It also works with lobbying the government about the importance of the sugar industry, and the need for the government to develop labour skills and improve transportation logistics for the industry to remain (Cortez, 2007; Evangelista, 2007). It manages the main sugar exporting port and has also collected funds from its members to modernise the port, resulting in a 75% decrease in the cost of exporting sugar through the port, and a 40% reduction of time in the exportation process (Evangelista, 2007). There is also a Sindaçúcar Alagoas, which organises the mills in that state. Sindaçúcar operates the container port in Maceio, the capital of Alagoas, and is planning to build a new and deeper one, expanding from 10 to 14 metres, and to connect it with pipelines (Evangelista, 2007). Sindaçúcar also are financing experiment stations of RIDESA.

Bioenzima has been producing commercial enzymes for the textile industry and for water treatment since 1997. In 2008 it applied for a patent related to hydrolysis through enzymes, which provides industrial methods for hydrolysis of sugar bagasse. The hopes are that the technology can increase production output by 50% (Simões, 2007c). The plan is to grow from the present 6 persons to 70 in two years. In developing the technology, they have collaborated with 16 Brazilian universities, both local universities from Pernambuco (Universidade Católica and the federal university of Pernambuco, UFPE), and also with the Federal University of Rio Grande do Sul (UFRGS) and researchers in the Department of Biological Sciences, University of Caxias do Sul (UCS). The project has received support of BRL 4 million, from FINEP and the owner of Bioenzima himself has invested BRL 3 million (Ramos, 2009a). In commercialisation of their invention they are working with Swedish researchers, ethanol producers from

Colombia, and a group of American investors in creating a pilot plant in Colombia with the technology (Ramos, 2009b).

4.9.3 Quasi Hierarchy Arrangements

4.9.3.1 Intense Competition

Quasi hierarchy arrangements have not generated positive benefits for innovation by enhancing intense competition. If anything they have pressured weaker actors, and in combination with networks and state arrangements decreased competitive pressures by protecting vested interests (Storel, 2006; Goulart de Miranda, 2007; Armijo and Kearney, 2008).

4.9.3.2 Knowledge Spill-over

The mills are important in developing knowledge, but they also allow universities and research institutes to try out new technology in their premises (Almeida, 2007). In the North East there are few examples of spin-off firms. Mills are also training their labour; for example, Coruripe is training labour and also providing basic education for seasonal labour (Almeida, 2007).

4.9.3.3 Specialisation

From 1970 to 1990 there was a period of consolidation in the industry, and also a diversification into ethanol production. Since 1990, however, there has been increased specialisation, and also more outsourcing of different kind of services. The large firms are increasingly using external suppliers, and outsourcing activities. The stronger firms are also building up complex and skilled competencies in-house, which create opportunities for more skilled labour in the region. Even though millers have widened their product range, and diversified their processes, they are outsourcing more of their other activities (Almeida, 2007), such as the use of seasonal labour for harvesting and the renting of transportation vehicles during the harvest.

There is a break-up of a system in which employees lived in a factory close to the village and sugar factories provided a life-long relationship, with schooling, health care and the setting up of opportunities for wives, the so-called Moradores system. Now it is more market based relationships, where employees live in nearby villages instead and the relationships are no longer life-long. Workers have higher salaries, but need to buy services on the

market or receive them from the government (Dubeaux, 2007). This change in system makes people less connected to the place and the firm. It opens up for some specialisation among suppliers, though. Firms have also begun to increasingly use seasonal labour from the backlands of the state (Dubeaux, 2007; Almeida, 2007).

SEBRAE (2007), which has made a survey of the potential of the sugar industry in the North East in the future, estimates that there will be even more outsourcing of services in the future. Respondents among millers said that they already were buying services for construction and maintenance, but would prefer to purchase services, such as transportation of labour, cane, feeding, housing security, health, education, commercialisation and technical assistance, activities that were not the core business or were not used frequently (SEBRAE, 2007). As there is a shortage of skilled labour, the millers, sees a challenge in upgrading their operations and to mechanise harvests, however they would be interested in buying this service from outside providers (SEBRAE, 2007). However, currently much of this was not available or some of too low quality.

Grupo JB and other millers are producing some of their own cane, but also buying from independent suppliers. There is a fear among independent growers that this practice is about to end (Morais de Andrade, 2007) and that mills will produce everything in-house. There is some support for this fear, as the percentage bought by millers is decreasing in the North East. In the 88/89 harvest, in Alagoas 58% of cane was produced by mills themselves and the rest was bought by external growers; in Pernambuco the figure was 45%, while in São Paulo it number was 57%. In the 08/09 harvest the figures were Alagoas 63%, Pernambuco 59% and São Paulo 50% (MAPA, 2009). At the same time the millers spoken to in the North East (Neto, 2007; Almeida, 2007) saw the process of buying externally grown cane as a means of risk management, coping with fluctuations in demand and prices.

4.9.3.4 User-Producer Learning

As some of the firms increase the use of science and technology, there are also more possibilities for specialised suppliers such as consultants and research institutes. Grupo JB serves as a test bed for technology developers. However, they claim that the majority of the technology comes from the Centre South, but is tested and implemented with them (Neto, 2010). Usina Coruripe is more active in participating in and jointly developing new

technologies. They collaborate with local universities and local technology providers that both develop and adapt technology for their needs, such as control systems for irrigation and diffusion of fertilisers in irrigation (Almeida, 2007).

4.9.3.5 Joint Action

Dominant actors are important in trade associations like Sindaçúcar, but there are no other indications of joint action.

4.9.4 State Arrangements

4.9.4.1 Intense Competition

Before the deregulation, market arrangements in the sugar industry were restricted, but by the end of the 1990s there was competition in place. In this period the role of the government altered from organising markets and deciding who could set up plants (Signorini et al., 2010) towards enabling it (Dubeaux, 2007; A. Andrade, 2008). There are still some protective measures in order to reduce the competitive pressures and the elimination of industry, the Brazilian sugar quota to the US (Bolling and Suarez, 2001) and subsidies of BRL 5.00 per metric ton of sugarcane up to 10,000 metric tons per grower (USDA, 2010).

These measures created an over-establishment within the industry and the region, with an over-use of land, creating congestion and pollution problems. The protective measure also allowed firms to spread themselves, and to use hilly land, with lower levels of productivity. As protection has been removed, these areas can no longer compete. Furthermore, there has been less implementation of modern agricultural practices among sugarcane growers, both small ones and among mills, which also prevents them from reaching competitive levels of productivity (Morais de Andrade, 2007; T. Andrade, 2008). Hence, the industry is shrinking and negative dynamics of a cluster appear; suddenly there are massive numbers of people who have skills that are not required. It is also likely that there will be more structure rationalisation, meaning that there will be more lay-offs in the future and in particular for unskilled labour. There will probably be increased opportunities for labour with mechanical skills, but there is a need to re-skill the labour force for this (Almeida, 2007). Some of the labour is moving to other parts of the country and some are moving to the cities to seek

opportunities in other industries. The expansion in Minas Gerais and São Paulo has to some extent been facilitated by labour from the North East, but this could perhaps be seen as an opportunity to remove some of the pressure in the region, and it can provide remittances from emigration labour. Also, the mills of the North East are moving capital equipment to other regions of the country

4.9.4.2 Knowledge Spill-over

State arrangements are enabling spill-over by financing education and research, which creates spill-over to the industry. In the region there are public universities (UFAL, UFPE) that were part of Planalsucar and now with RIDESA. The researchers from the universities and from the specific research centres connected to RIDESA do research within the programmes on new cane varieties (Dubeaux, 2007), and also contract research for mills, and the students collaborate with the industry and do their theses in the mills and plantations, in which they are often employed later (Simões Neto, 2007). However, the indications are that there has been less specific technology developed for the region than in the Centre South, but that it is increasing (Almeida, 2007; T. Andrade 2008). For example, RIDESA is launching a new range of cane varieties that are better adapted to the North East in 2010 (Camarotto, 2009).

There has not been any substantial new firm start-up, but rather a protection of incumbent actors. However, in recent years there has been an increased focus on supporting new firms and also providing financing schemes for business development, such as through SEBRAE, which gives support to aspiring entrepreneurs both through financing schemes and through training (Alexandre, 2007; Bezerra, 2007; Correa, 2007).

4.9.4.3 Specialisation

State arrangements are enabling innovation through support to upgrading and business development within existing firms. There are federal programmes, such as the BNDES and the Science and Technology Ministry's (MCT) joint programme FINEP, which finances loans for investing in sugar mills, as well to increase mechanisation. Thirty per cent of FINEP's funds are targeted for the North, North East and Centre West. BNDES also has the programmes FINAME and BNDES Inovação (BNDES, 2010b). As an example here, the Coruripe Mill received a loan

from BNDES to build a dam at the centre of its irrigation system. They argued that this model was preferable to having the dam built by the government, that this model was more cost-effective and more adequate to their needs, as they were more knowledgeable about costs involved, and appropriate requirements of the dam; also, there would be less corruption involved (Almeida, 2007).

There are also regional financing schemes and actors that manage federal funds. Banco do Nordeste (The North East bank) has specific funds for small and micro firms that are about to innovate, called the Financiamento do Nordeste Inovação; half of the funds are for the agricultural industries. Banco do Nordeste also has the programme O Cresce Nordeste that provides loans for modernisation of agro-industrial plants, new processing practices, introduction of new products and exportation of products from the sugar and ethanol industry (Banco do Nordeste, 2010a). Grupo JB received a loan from Banco do Nordeste to develop the unit in its mill that produced carbon dioxide for the soda industry (Neto, 2007)

The Banco do Nordeste (2010b) is also supporting research and technology diffusion in the North East, through its Scientific and Technological Development Fund (FUNDECI, Fundo de Desenvolvimento Científico e Tecnológico). The fund was set up in 1972 and projects were selected at the beginning; in the sugar industry they supported the establishment of an experiment station in Alagoas (the EECAA) and funded the training of personnel in the ethanol industry of the North East for the IAA and EECAA. As of 1995, the fund established rounds of financing programmes, where criteria were posted in advance, and applicants from the region were encouraged to seek funding in a competitive process; since then there have been projects together with the Federal University of Alagoas (UFAL) to explore alcohol fermentation from sugarcane yeast, and diversification projects for alternative sugarcane technologies.

State arrangements are also supporting specialisation through the establishment of universities and research institutes. Alagoas is stronger in science and technology than Pernambuco; for example, all the seedlings for all of the universities in RIDESEA are produced there. There are 16 PhDs working on genetic improvement in the lab at the Federal University of Alagoas. In Pernambuco there are only 3–4 (A. Andrade, 2007). The research facility in Pernambuco is part of the RIDESEA network, which

consists of 11 universities and institutes all over Brazil. They have different assignments in the country, but they use their distributed capacity to match the different harvesting and growth seasons, as well as the different climate circumstances in order to test and develop varieties. In Carpinas, at the Federal University of Pernambuco, they do R&D on new cane varieties and pesticide control, biological means to control vermin, and processes to handle vinasse. They have also projects with polymers and chemistry (Simões Neto, 2007). The institute collaborates with the industry and the researchers sometimes do contract research and their students have assignments with the industry, where they are later employed. The institute is financed by a percentage paid by the larger mills. Simões Neto (2007) estimates that, thanks to the genome project, they can test 2.5 million genetically distinct sugarcane varieties in the RIDESA programme. In March 2010, they were to launch 13 new varieties of cane sugar, which are the result of 15 years' work. The aim of seven of these varieties is to increase the efficiency of production in the North East region. Simões Neto, co-ordinator of RIDESA in Pernambuco expects that the use of new varieties will increase productivity in the North East by at least 17% over the next three to five years to 70 tons per hectare. Furthermore, he expects to raise by at least 10% the ATR rate (Total Recovered Sugar), which measures the sucrose content of sugarcane. The idea behind the new plants is to increase planting options and prolong harvesting seasons. The varieties have a higher tolerance to water stress, which is a common problem in the North East. They are also more tolerant to pests and diseases. RIDESA also works on other fronts to increase the productivity of the North East, with regard to improvements in soil and treatment of diseases (Camarotto, 2009).

In the research lab of the University of Alagoas they create genetically new breeds of sugarcane; they are also in charge of the facility in Serra do Ouro, which is the heart of the new breed programme (Dubeaux, 2007). In this location all the new seedlings are created that are later distributed to other universities and tested in locations in the mills. There are plans to set up a bio-lab in Pernambuco. This would use Cuban technology to produce 1,500,000 seedlings per month; currently there is only a production of 200,000 per month in the state. This project is supported by the Strategic Centre of the Ministry of Science and Technology in Pernambuco (A. Andrade, 2007).

The North East is a poorer region with large shares of the population living in poverty with little education. The lack of skilled labour is also something that is indicated as a problem for further specialisation and upgrading of firms, and for development of more specialised suppliers (SEBRAE, 2007).

4.9.4.4 User-Producer Learning

The state has stimulated the growth of ethanol as a product in the North East; before the Pró-Álcool programme, very little ethanol was produced. The production mix has gone from none to a mix of 70% sugar 30% ethanol in Pernambuco and 60% sugar and 40% ethanol in Alagoas (MAPA, 2009). The Pró-Álcool programme and subsequent mixing in of ethanol in the petrol create a steady demand for producers. This has however led to less influence on development of the supplier industry. Brazilian demand is an important factor for the production of ethanol; in 2008, export volumes in the North East were 21%, accounting for 10% of total exports (Unica, 2010), whereas for sugar 72% is exported, accounting for 15% of sugar exports total.

Through legislation there will also be stimulation of innovation and upgrading. It will be prohibited to burn cane, and also to flush out vinasse into rivers (A. Andrade, 2007; Arruda, 2007). As a response many firms will mechanise, which will create a demand for new skills and machinery.

4.9.4.5 Joint Action

State arrangements introduced the Planalsucar and Pró-Álcool programme, which aimed at breaking lock-in, and this did succeed in creating a diversification into ethanol production in the North East. At the same time there are indications that state arrangements through IAA fostered non-competitive practices and protected non-competitive firms that were not sustainable in the long term and may have hampered necessary restructuring of the industry. There are still many firms in the North East that have not appropriated new technology. It has also been more labour-intensive as there has been a ready surplus of manual unskilled labour. However, when the industry is shrinking and there will be increased mechanisation within a not too distant future, there will be fewer opportunities for unskilled labour and an increased demand for skilled labour, which does not exist at the moment.

There is a need for retraining and also an opportunity for upgrading labour. A large share of the unskilled labour has very little education at all, though, and they are therefore not easily trained for more skilled professions (Almeida, 2007; Evangelista, 2007). There is also a problem that skilled labour is leaving the region for the Centre South, as salaries and labour opportunities are better (Dubeaux, 2007; Arruda, 2007). There are discussions between the government and millers about retraining of labour (Evangelista, 2007; Almeida, 2007; A. Andrade, 2007).

However, the region is already using almost all available land for growing cane. There is no more productive land available in Pernambuco and only some in Alagoas. For a long period of time there have been plans to develop the inland of Pernambuco in a project of using the São Francisco River to irrigate the dry lands. The state government is carrying out discussions with a consortium from Japan. This could potentially create space for another 6–7 sugar mills and increase sugarcane output by 30% or 10 million more tons of sugarcane, as the terrain is potentially highly productive (A. Andrade, 2007). Some argue, though, that it would be better to use the land for other types of fruit that are easier to transport and render higher prices (T. Andrade, 2008). Alagoas has fewer problems of this sort and still some terrain on a flat plateau that can be developed.

SEBRAE is also active in supporting cluster initiatives in the sugar industry, such as networks for producers of art-craft products related to the sugar industry and the creation of a concept within experience tourism. This is a collaborative marketing of a tour to historic sites of the sugar industry, showing museums, and including restaurants with traditional food from the mills (Moraes e Silva, 2007). They are also promoting business opportunities for relatives of employees at the sugar mills (Moreira, 2007).

4.9.5 Summary of North East

The sugar industry in the North East is not as dense and diversified as in the Centre South. There are fewer actors, suppliers, research institutions and less variety in the service and products offered by these actors than in the Centre South. There are also fewer networks than in the Centre South and these to a greater extent than in the Centre South focus on lobbying the government for advantages, rather than finding other solutions to improve productivity and competitiveness. There is also less skilled labour available and less implementation of technology in the North East than in the Centre South.

Before 1990, state arrangements were dominant, with influences coming also from quasi hierarchies and less from markets and networks. For the development of the industry, it seems less driven by cluster factors, and more by federal state arrangements, national and international markets.

State arrangements have been and still are stimulating the cluster to grow and diversify into ethanol through procurement, stimulating user-producer relations and specialisation through the Planalsucar and Pró-Álcool programme. At the same time there have been problems of vested interests, and the cluster has grown beyond sustainable levels from the stimulating and protective policies that removed incentives to innovate. This locked the region into practices that it could not keep up long-term and also fostered an expansion into lands of little productivity. There are voices that claim that firms in the North East are still not using technology enough. Tadeu Andrade (2008) who is R&D director of CTC, argues that the firms in the North East do not deploy technology sufficiently, but depend more on political decisions, and likewise the agricultural manager of the Coruripe mill claimed that many of his competitors in the North East were complaining too much about their conditions and should begin to implement more new technologies (Almeida, 2007).

Since 1990 the role for markets has increased and so have the competitive pressures, not only from local actors but also from the outside, from São Paulo and other states of Brazil. The increased role of markets has been painful, with many bankruptcies and many lost jobs. At the same time it has increased pressures to innovate among firms in the region. Since 1990, it seems as if market, quasi hierarchies (in the form of the dominating mills) and state arrangements have been important for innovation. There has been more innovation after 1990, but still not so many original innovations coming from the North East, as in the Centre South; it is more a matter of implementing technology developed elsewhere.

The division of labour has increased somewhat, but not to any greater degrees. There are a few specialised suppliers and firms offering more diversified products and services (SEBRAE, 2007) and more advanced process technology is starting to be incorporated. There are not so many spin-offs and start-ups in the North East as in the Centre South, but there are interesting examples like Bioenzima that, through high-technology solutions, can potentially increase the productivity of mills radically (Ramos,

2009a). The special terrain conditions have led to the development of the Implanor machinery, but otherwise there are not many examples of special innovations due to local conditions.

Even though there are almost no patents, the number of scientific articles is increasing, and there is more activity within universities and research institutes (Dubeaux, 2007; Simões Neto, 2007). RIDESA has launched a series of new varieties that are specialised for the North East (Camarotto, 2009). Productivity in sugar, sugarcane and ethanol production is also increasing. There is also less educated and specialised labour in the region, and many people with skills leave for the Centre South for the better job opportunities there. Likewise, firms are moving to the Centre South to establish themselves in more productive regions.

Within a not too distant future there will also be increased mechanisation that will create new opportunities within mills, but also among suppliers, and harvesting service providers and suppliers of equipment and repairs. There is also potential through the development of equipment adapted to the local terrain (the local company Implanor is growing), and for specialised services in logistics, maintenance of industry and equipment (SEBRAE, 2007).

Local networks were not as strongly connected to supporting innovation through cluster externalities. There seem to be fewer networks, and these seem to be more focused on state protection, even though there are some organisational innovations to address joint problems, such as operation of exporting ports (a practice they have taken over from the local government), some research activities and price negotiations. Much of the activities seem less focused on innovation than on protection. The reason can be due to the economic distress of the North East, and the outcome of previous state arrangements that has fostered this type of culture, but there were also indications that firms are unclear about how they can interact in networks, after deregulation (Neto, 2007).

One area where the case of the North East is particular is when it comes to community-based network arrangements. In cluster literature it is often referred to the role of social capital and community-based networks as a foundation for collaboration. This has not been acknowledged to any great degree in the other cases, in the North East it can help in explaining how the drives for increased specialisation and mechanisation have been stalled by

community agreements, between employers and trade unions and also the public sector (A. Andrade, 2007; De Santana, 2007; Almeida, 2007). However, it is likely that in a not too distant future this consensus will be broken. Here it seems that different kinds of network and state arrangements have prevented further specialisation, but changes in institutional framework will likely take place as market arrangements create a pressure for further specialisation.

The role of the state arrangements has also altered. There is a move away from being at the centre of activities towards creating an enabling framework, supporting innovation activities and linking actors, but the main actors carrying out innovation are private firms. The focus is on keeping the macro economy in place, investment in research, loans for mechanisation and building sugar plants, education. One example is how the government has provided a loan to Coruripe for the construction of a dam, instead of building it (Almeida, 2007). When it comes to funding of research and innovation activities, there are likewise more market influences, in that firms in some programmes compete for funds, instead of the government picking winners beforehand with whom they collaborate, as with the FUNDECI fund from Banco do Nordeste.

There is still regulation concerning the procurement of ethanol, by making it mandatory to blend a certain percentage of alcohol in all petrol; it is also mandatory to keep ethanol in filling stations. But there is also support for export trips and for internationalisation, and special programmes to support small firms, e.g. Pro-Biodiesel. Also, there are protective measures in the North East, with the Brazilian quota for exportation to the US, in order to protect the poor, and production subsidies to sugarcane growers. These measures are important to secure incomes for firms in the North East,

Table 27 gives a summary of how institutional arrangements have influenced cluster externalities to have an impact on innovation in the North East.

Table 27: Summary of institutional arrangements and externalities in the North East of Brazil

	Intense Competition	Knowledge spill-over	Specialisation	Demand	Joint action
Market	Strong driver for diversification Shortage of skilled labour	Spill-over from increased labour rotation Some start-ups, in services	More outsourcing, More consultants and external relations. Division of labour between mills and consumer brand firm	Implanor outcome of local conditions Delivery to other markets where there is hilly terrain Pressure to certificate	Little indication
Network	Community concerns prevent mechanisation Lobbying to reduce competitive pressures from national and international actors	Some knowledge exchange in informal networks, but less, and through formal networks	Division of labour from mills to Pitú.	Interaction with suppliers and universities with mills to try out technology.	Price negotiating Lobbying Handling port Sindaçúcar is co-funding the RIDESA experiment station.
Quasi hierarchy	No	No	Increasing outsourcing	Some local interaction.	Mills are co-developing with universities and suppliers
State	Few indications Subsidies and quotas Mills & cane growers receive preferential treatment, such as US quotas and subsidies.	Education Research Support to start-ups	RIDESA research for North East, Financing for business development from BNDES and Banco Nordeste	Procurement of ethanol important Legislation environmental concerns.	Some cluster initiatives but more for micro and small companies, sugar tourism. Lack of land & lock-in of older practices, and less use of technology.

4.10 Cuban Institutional Arrangements

4.10.1 Market Arrangements

4.10.1.1 Intense Competition

In Cuba the economy is centrally planned. State arrangements dominate, with strong top-down structures. There is some private ownership, but no markets for transactions of land. It is not possible to trade property, and prices for products and services are decided by the government. Furthermore, even if prices were to favour a certain decision and investment by a private firm, in the sugar industry they cannot decide to change their production completely, without consulting the sugar refineries or the ministry, as they have specific social obligations. Hence the price-signal mechanism is very weak in the Cuban economy. There have been a few changes the last few years that have increased the scope for individual farmers and there is currently a reform programme being discussed on Cuba that will create major changes. In November 2010 a document entitled *Draft Guide for Economic and Social Policy was diffused* (PCC, 2010), with the purpose to spark and shape public discussion on topics that will be the focus of the long-postponed Sixth Congress of the Cuban Communist Party to take place in April, 2011. Topics include, more decentralized decision making for firms and policymakers, insolvent firms will face liquidation, incomes will be related to firm performance, reduction of state employment and studies carried out on how to merge Cuba's two currencies. Augmentation of sugar production to promote exportation, to improve relations between mills and sugarcane providers, implement mechanism that better diffuses the internationally favourable sugar prices to sugarcane producers; to increase the production of sugarcane derivatives, prioritizing alcohol, food production, animal feed and to promote generation of electricity from bagasse. Still, in the document there is a declaration that prices will be centrally determined.

Over the years there has been a pendulum going from centralisation to some decentralisation, meaning that there has been more scope for private Cuban firms in some areas. This pendulum is connected to the situation of the economy. When the economy allows for it, the government tightens control of the economy and centralises it. However, these policies hamper the economy, which then after a few years forces changes to decentralisation,

which leads to some economic recovery, which is later followed by centralisation again (Brundenius, 2002). There are however many indications that market arrangements would be an important contribution to revitalising the Cuban sugar industry.

Currently non-state production is dominating in sugarcane production, whereas most other activities of the sector are carried out by state-owned firms. Non-state companies consist mainly of co-operatives in different shapes, and some individual farmers. These organisations produce not only sugarcane, but also other types of agricultural products. In the last few years the scope to decide which products to grow and where to sell them has begun to increase. The more individual decision space allowed, the more productive the units. There has been research exploring the efficiency of different units and tests with individual farming within co-operatives. The result is that the incentives matter and that the greater individual responsibility and rewards, the higher the productivity (Fernandez Dominguez, 2006). There are indications that individual farmers have been able to achieve yields of 100 tons cane/ha and higher, which is double the average of the best periods in Cuba, and higher than the average in São Paulo (Alonso-Pippo et al., 2008). Most of the sugarcane, however, is still produced under forms that are either controlled by state or quasi hierarchy arrangements.

The effects of intense competition are non-existent in Cuban clusters and there are few incentives for the independent production units to run production more efficiently in Cuba. There have been limited possibilities to alter production (Martinez, 2008), both when it comes to decisions about production – in 2008 producers had to sell 80% of production to the state (Grogg, 2008) – and also in production processes, as most supplies (e.g. fertilisers) are sold and controlled by state suppliers. Another problem is Cuba's dual currency system, which does not allow for high international prices for sugar to be reflected in local prices, and this does not stimulate farmers to increase production (Nova Gonzalez, 2006). Payment for cane has been in the local currency, but vital supplies have been sold in convertible currency, which has created problems and disincentives for production, as it is more important to earn foreign currency, but also hard to get proper supplies if not earning convertible currency (Dominguez, 2004). There are also incentive problems related to a lack of gains from increasing productivity, as incentive programmes reward extra production

modestly (Leon Gimenez, 2008) and there is a lack of higher payments for better quality cane with more sugar content. These payments are based on the average of the sugar content of all suppliers to a centre (Alvarez, 2005).

Furthermore, there is no risk of bankruptcy, which is not allowed, and the government covers up the debts of unproductive units (Fernandez Dominguez, 2006). This hampers the development of new practices, as winning concepts do not expand and poor organisations go out of business. The pressures on productive units are not high to innovate or to improve productivity. The outcome of these problems is a radical decay in the provision of sugarcane, and falling productivity in the sugar industry. In total there has been a fall in yield of sugarcane and in the industrial yield, see table 11. There has also been little innovation in recent years.

Since 2008 when Raúl Castro took office, there have been stepwise reforms to improve productivity in the agricultural industry. The idea was that more decentralisation would provide more incentives to produce food locally, and reduce needs for importation. The government decentralised control of government-run farms from Agricultural Ministry officials to local farming boards, with hopes to boost productivity. It also put idle state land into the hands of private farmers, and private leasing of unused and inefficient land up to sizes of 100 ha for periods of up to ten years has been allowed. The initiative is probably not mainly for sugarcane production, but an effort to try to stimulate agricultural production in order to decrease the need to import food (Booth, 2009). The government continues to provide seeds, fertiliser, petrol and other supplies to farms and buys almost all production (AP, 2010). At the same time a number of stores are opening up that offers agricultural supplies freely at market prices; initially there has been limited number of goods, such as picks, shovels, machetes, work clothes and gloves (Frank, 2010a).

The pressed economic situation and what has been a lack of opportunities to gain salaries, and most importantly to gain convertible pesos in the sugarcane production sector, has provided incentives for farmers both to diversify into producing other types of agricultural products, and to carry out activities in the informal markets.

Since the reforms, private farmers can also sell certain quotas of their crops to the local farm co-operative; the state sets the price, but farmers can sell as

much as they please, and better-quality products receive higher payment. The production that is beyond their assignments they can sell freely. Furthermore, as part of the reforms, prices for agricultural products were doubled and tripled (Miami Herald, 2008a). High international sugar prices has also induced the government to double the price for sugarcane for the coming harvest of 2010/2011, still the prices are not sufficiently reflecting international prices (Nova Gonzalez, 2010). So far the outcome of Raúl Castro's reforms is unclear. However, private farmers are still lacking in a number of resources to really take off, such as fertilisers, seed, fuel and pesticides (Booth, 2009). The Communist Party newspaper Granma said Havana province fell short of its targets largely because of government ineptitude (AP, 2010), as authorities failed to provide farmers with seeds, fertilisers and other nutrients to bolster crop. Agriculture has also started to use oxen, as fuel costs for tractors are too steep (Weissert, 2009).

Another very important area in which many Cubans are diverting their efforts are the informal markets, where there is trade in unlicensed services, goods from abroad and goods stolen from the state (Miroff, 2009). In these markets, products and services are offered, such as pirated cable TV, with US stations such as the Discovery Channel in Spanish and Playboy, and illegal home improvements and room rentals (Adams, 2007). There are also many stories of corruption and trading in goods stolen from the public industry. There are also grey zones where joint ventures receive privileges, and work both in formal and informal industries. The informal markets have so far relied on word-of-mouth, among friends and colleagues, but there has been an innovation bringing it out on the Internet, despite its limits on Internet access for ordinary Cubans, is that there is now an online classified list/Ebay type of service that sells goods and services, called Revolico.com (Lacey, 2010). These markets are substantial and a way for many Cubans to acquire much needed goods and services, and ways to make an extra income to compensate for low wages. Incomes on the black market are much higher; e.g. a bicycle repairer can make 2000 pesos a month, and can in one day make what state workers do in several weeks (Adams, 2007). All Cubans are involved in these processes, even the most devoted party members (Gustafsson, 2006). The government has also released a report on the development of prices in the informal industry, where they surveyed

development in the free agricultural markets, but also considered illegal activities (Rodriguez, 2008).

In Cuba, in the sugar industry, there is limited presence of market arrangements, even if it is increasing slightly. The role of personal and transparent rivalry is of little importance in the context of Cuban clusters.

4.10.1.2 Knowledge Spill-over

There is little knowledge spill-over from market arrangements, due to the restrictive state arrangements .

There are no free labour markets, and knowledge spill-over from labour rotation is limited. Firms cannot decide independently who they want to employ (small firms can only employ relatives, and foreign firms are assigned employees). Cubans can so far, neither move freely within the country nor look for employment. Moving in Cuba is not allowed without permits, which is part of a policy to prevent urbanisation. In order to prevent more clustering in the capital, the government pursues active policies; this was successful up to the Special Period, but after this, there were not enough resources to develop other parts of the country, and there was a strong current of migration to Havana (Cubaheadlines, 2008). In 1997 a law was introduced that prevented people from moving to Havana.

Foreign firms have complained that they cannot employ the people they want to and that it is common that people they have employed and trained are then later taken away from them and employed elsewhere (Dominguez, 2004).

It is hard for small firms to amass resources to invest, and due to the institutional set-up the incentives are not in place to do it. There are small-scale informal firms, and small agricultural actors who are much more efficient. In the present situation, however, these cannot expand their operations; they are not entitled officially to acquire more land, or hire more people and run the risk of being clamped down, and therefore successful practices have a harder time diffusing in the economy. Likewise, firms in informal sectors are always in danger of being closed down one day, despite the success of Revolico.com. Therefore it is problematic to develop innovations that are successful and a limiting factor for Cuba's potential to develop innovations.

At the same time, with the new reforms under way there are hopes that large parts of the informal economy will turn formal. The outcome is still unclear, however, regarding which firms and which industries can employ more freely and to which extent. Cubans can now legally buy building materials and mobile-phone connections, and sell services such as hairdressing and building work. At the same time as the government is loosening its grip, officials are increasing their efforts to remain in charge by clamping down on corruption (The Economist, 2010b). It has also been announced that employment in the public sector will be decrease by 1 million people within a few years and by 500,000 people within a year. The idea is that these will be taken up by the private sector (The Economist, 2010c). However there is much debate whether this is possible within the existing system, as small firms are not allowed and do not have the means to expand ()

4.10.1.3 Specialisation

There are great inefficiencies and misallocations of resources in the economy; even potentially viable industries can have a hard time recruiting labour. Cuban industries that provide goods and services to tourists have become very popular, as these give opportunities to gain foreign currency and relatively high wages compared to salary levels in parts of the economy that do not cater for foreigners.

As described in previous sections, when there are the right incentives in place, labour and producers can increase sugarcane yields, if the right arrangements are also in place. This is reflected by the economic activity that rises in industries when market activities have been allowed (Perez Lopez and Alvarez, 2005), but also in the activities in the free markets for agricultural products. One could therefore expect there to be more specialisation, among both labour and firms, if there were other arrangements in place.

There is good labour with high science and technology capacity and also interesting geographical conditions, which represents great potential to invite foreign firms to invest in Cuba.

4.10.1.4 User-Producer Learning

As the government is ambiguous about its ambitions and attitude towards the sugar sector, there are challenges for the further development. For a long time foreign firms could not invest in the sugar sector (Alvez, 2005), as has been allowed in copper and tourism, which may be due to strong sentiments related to the sugar industry. However, by 2008 there were seven in place, with capital from Spain, Italy, Canada and Mexico, all of which concentrate on the diversification of the sugar industry (Grogg, 2008). For a number of years Cuba has also been collaborating with Pernod Ricard for exportation of rum. These relations have generated good incomes and also knowledge. The outcome so far of these foreign joint ventures and their impact on innovation and upgrading in the sugar industry is unclear, but the production and exportation of rum for consumption is increasing; from 2002 to 2008 the production rose from 709,300 to 960,800 litres (ONE, 2008b).

There have also been discussions about allowing Brazilian firms to take over parts of the sector, in order to upgrade it (UPI, 2010).

4.10.1.5 Joint Action

Local market arrangements affecting these cluster externalities did not matter for innovation.

4.10.2 Network arrangements

4.10.2.1 Intense Competition

It is hard for people to organise themselves into larger units outside state arrangements, and local network arrangements affecting this cluster externality did not matter for innovation.

4.10.2.2 Knowledge Spill-over

There is little local initiative and little innovation coming out of local network arrangements. Rather it is the connections with the national ministries, and their research centres and technical extension arms are more important for knowledge spill-over and new technology development. For example, the Hector Molina Refinery, see Appendix 8, works with the research institutes, notably ICIDCA and INICA, and with the University of Havana, which has a special unit for research on agriculture. They allow

both for student research projects in the mill and for writing of student theses (Martinez, 2008; Caballero, 2008). These units and relations are more of national than local character. There is also interaction with the research institutes with their consultancy arms that diffuse knowledge about clusters and from informal networks created by students in the institutes from the plants (Mondeu Gonzalez, 2007).

4.10.2.3 Specialisation

There are arrangements that can be seen as somewhere between firms and local networks, the co-operatives and their associations. No pure community-based arrangements of major importance for the sugar industry have been found. Much of the civil society and community-based networks were changed after the revolution, when communities became integrated with state arrangements. Local refineries and co-operatives are obliged to produce certain foodstuffs and supply them to community members as part of their social obligations (see Appendix 7 and 8).

The co-operatives are self-organised units, but they are very much controlled by local sugar refineries and the Sugar Ministry, which makes the relation more like a quasi hierarchy or a conglomerate. There are regular meetings between the main actors in the clusters, but it seems as if it is not easy for ideas generated from the bottom up to grow and develop. As the co-operatives are limited in which decisions they can take, they cannot provide different salaries or incentive schemes, they cannot decide to produce something else, they cannot fire employees. Their options to change operations to improve productivity are thus limited (Leon Gimenez, 2008).

4.10.2.4 User-Producer Learning and Joint Action

There was little indication of network arrangements affecting these cluster externalities to have an impact on innovation.

4.10.3 Quasi Hierarchy arrangements

4.10.3.1 Intense Competition

Local quasi hierarchy arrangements affecting this cluster externality did not matter for innovation.

There are a number of joint ventures in Cuba that to some extent can be seen as quasi hierarchies. There are some challenges related to how they are

set up; the investment regime has had a tendency to give rights to specific areas of industries or territorial areas to firms that receive protection from competition from other actors and oligopolies are created, which does not stimulate productivity (Dominguez, 2004). The granting of these rights also fosters corruption. Foreign firms have complained about difficulties in hiring labour freely and not being restricted to the personnel from the ministry involved in the joint venture. Other problems are that when personnel have been educated they are transferred elsewhere, employers are subject to limitations on offering labour-incentive schemes, and the state sets prices too high and creates unexpected taxes (Dominguez, 2004).

4.10.3.2 Knowledge Spill-over

In Cuba there was always private production of agricultural products, such as sugarcane, but the actions of private farmers are controlled and dominated by the sugar refineries, which also in turn are tightly controlled by the Sugar Ministry. In this chain one can see the relations as an interaction of quasi hierarchies and state arrangements. The Sugar Ministry research institutes, such as ICIDCA, INICA and ICINAZ, develop and diffuse new sugar technology and varieties to mills and to local growers, as an outcome of state arrangements and quasi hierarchies. The refineries are important for co-ordination of activities and for education of people around the refineries, see Appendix 8. As the production units around a sugar refinery are co-ordinated, there is knowledge spill-over between the actors to some extent. They also provide personnel as teachers at the decentralised universities, SUM.

In recent years there have been establishments of foreign firms in Cuba which are also altering the local economic dynamic. In 2008 there were 319 foreign companies operating in Cuba, 75% in joint ventures with Cuban entities (Grogg, 2008). In the sugar industry, as mentioned, there are 7 joint ventures. This creates an influx of new knowledge and education of human capital.

4.10.3.3 Specialisation

After the Special Period, the refineries are diversifying their production output, as well as their production units, into different groups. When planning production output, the refinery decides – together with local authorities and the ministry – what to produce. For example, the Hector

Molina Refinery produces, besides sugar: alcohol, milk, yeast, animal feed, meat (pork and beef) and electricity for the grid. They organise 36 production units in the surrounding region, 7 state farms which send their cane to the centre, and 29 non-state farms, of which 11 are UBPCs, 10 CPAs, and 8 CCS; the latter sell their material to the refinery according to contracts. However, these units cannot decide to change their production if the refinery objects to it. The management of the centre has the final word in discussions about production with the surrounding production units (Martinez, 2008; Caballero, 2008). Furthermore, they organise a harvesting unit, the CAMECO that has three mechanised harvesters. They harvest the refinery's land, and also sell their services to co-operatives. They also have units for technical services, units for transportation (they organise roads and railways) and construction, and the purchasing board (the Acopio) (Martinez, 2008; Caballero, 2008)

4.10.3.4 User-Producer Learning

Refineries, together with ministries, formulate demands as to what sugarcane producers should produce, and also diffuse knowledge locally, and to some extent, by interaction between refineries and ministries in developing knowledge. There are, however, some claims that the interlinkages between research and production units, such as the refineries, are weak and therefore much of the scientific output is not considered by the productive units (Fernandez Dominguez, 2006).

Some demand, for example for consumption rum, is now driven by partnerships and joint ventures with international partners such as Pernod Ricard.

4.10.3.5 Joint Action

Refineries are local leaders, and they influence the decisions in the vicinity. They therefore also influence the decisions of local producers, such as to produce food products in order to address social issues (Martinez, 2008). One can see the influence of leading groups within the party, and operating through ministries and refineries, blocking the entrance of innovation.

4.10.4 State Arrangements

4.10.4.1 Intense Competition

Initiatives for innovation are top-down driven; it is the central government (and often very important decisions have been decided right at the top, i.e. by Fidel, even in matters about which there has been a lack of necessary knowledge, Roca, 1976) that decides when advances are to be tried and in which sectors. The upgrading and innovation in Cuba comes from the top down and there is relatively little space for bottom-up experimenting, which reduces the possibilities for innovation both in the development of offerings and in the organisation of production.

Intense competition from local arrangements has been of very little importance; state arrangements have tended to block this externality.

4.10.4.2 Knowledge Spill-over

Cuba has an advanced science and technology capacity, and much effort has been invested in developing university and research institute capacity (Alvarez, 2005; Alonso-Pippo et al., 2008). Of specific interest for the sugar industry are the four R&D institutes that carry out research, arrange education, work with technological extension and diffuse best practices between productive units, and take part in and initiate innovation projects where refineries are involved. The institutes are networks for diffusing knowledge between productive units (Mondeu Gonzalez, 2007; A. Torres, 2008).

During the visits there were indications from some respondents, such as an official from the Ministry of Industry's sugar division, that there is a poor connection between academia and the industry and that the findings of academia do not reach industry and that industry's needs are not channelled in a proper way to the research institutes; the outcome of the R&D at the research institutes is therefore such that the industry does not bother about it (Fernandez Dominguez, 2006). Others from Cuban research perspective (Nova Gonzalez, 2006, 2008) said that these were unfair criticisms and that academia is producing good and relevant material, which is brought to the ministry to use whether it wants to or not. The findings are not always well received and final decisions are taken by the ministries.

The extension service is mainly arranged by the Sugar Ministry's National Institute of Sugarcane Research (Instituto Nacional de Investigaciones de la Caña de Azúcar, INICA). Its service unit works in three areas: i) since 1996 there is the Fertiliser and Amendment Recommendation Service (SERFE), ii) since 1998 there is the Variety and Seed Service (SERVAS), and iii) the Phytosanitary Service (SEFIT), which began in 2002. The institute also manages technology transfer, innovation, training, and knowledge diffusion (Alvarez, 2005).

The research institutes are important for the development of Cuba's sugar industry, and to quote Alvarez (2005, p. 5), "*Cuba has an impressive number of extremely well qualified scientists at all levels in ministries, universities, and other governmental agencies. The amount and quality of research related to the sugar agro industry is quite impressive. The problem is that, most of the time, valuable results are lost in a multitude of bureaucratic layers. On other occasions, recommendations cannot be implemented because the country lacks the resources to do so. The predominant problem, however, rests on the preference that the country's leadership places on politics over science in their decision-making.*"

4.10.4.3 Specialisation

State arrangements are behind education, research institutes, vocational training, export agreements, price controls, salary rates and different business development initiatives to differentiate the economy. At the same time, the ministries hold a number of other specialised units, such as exportation companies and commercial companies that sell sugar to the domestic market. The main actors involved in developing the sugar industry are the Sugar Ministry (MINAZ) and the four research institutes connected to the sugar industry.

Besides research capacity, Cuba has been strong in upgrading the production with mechanical harvesting. Before the revolution all cane cutting was done manually, even though a Cuban patent for a cutting machine was filed in 1857 (Perez-Lopez, 1991). Mechanisation was also opposed and prevented by strong labour unions.

Cuba's revolutionary economic planners were antipathetic towards sugar production and favoured diversification, in order to reduce the weight of sugar in the national economy. There was also a keen interest in import substitution strategies for rapid industrialisation. The first focus was to

allocate resources to the large farms that were taken under direct government control, in 1959–1960. Excessive enthusiasm and lax controls of the diversification programmes caused severe demolition of some of the most productive cane plantations in Cuba. The changes due to the revolution transformed labour supply to agriculture in general and cane cutting in particular. Greater urban employment opportunities stimulated urbanisation, as well as growth of rural construction activities and an expanding army that drained labour from agriculture. After 1959, small farmers could also increasingly concentrate on working their own lands and not work for others. In 1962 many co-operatives were converted into state farms where the membership included all workers of the land and year-round employment was guaranteed. This reduced labour mobility, together with more relaxed work attitudes and lower labour productivity, and freedom of choice between cane cutting and other jobs created labour shortages. Production plunged from almost seven million tons in 1961 to less than four million tons in 1963. With growing economic problems and deficits of balance of payments, Ernesto “Che” Guevara, then Minister of Industry, concluded: *“The entire economic history of Cuba has demonstrated that no other agricultural activity would give such returns as those yielded by the cultivation of the sugarcane”* (Pollitt and Hagelberg, 1994).

As the first initial efforts of rapid industrialisation failed, and with the increasing importance of Cuban-Soviet relations and the entrance into the COMECON, where Cuba was assigned the task of producing sugar, Cuba’s role as sugar producer was strengthened. Sugar was the main backbone for earning foreign currencies up to the 1990s, when it accounted for 70% of export earnings.

To meet the new opportunities and to address labour shortages, mechanisation programmes were initiated. A commission for cane harvest mechanisation was established as early as 1961. Loading of cane caused little problems; by 1966 around 3,500 Soviet built machines loaded about 45% of the crop and by the end of the 1970s there was no manual loading. Machines for cutting cane took a longer time, in 1970, the cutting of cane was only 1% mechanised, but by the end of the 1970s harvesting had become 42% mechanised (Pollitt and Hagelberg, 1994). At present harvesting is around 87% mechanised (El Nuevo Herald, 2008).

In the 1960s the Cubans also developed a proprietary design of a machine, called the *Libertadora*, which was more efficient than both the Soviet-technology-based KTP and one of the market leaders, Massey Ferguson from Australia. Due to the Cuban-Soviet relations, and the initial lack of manufacturing capabilities in Cuba, it was not developed locally, but traded to Claas Manufacturing in Germany in exchange for 170 harvesters (Perez-Lopez, 1991). Instead Cuba developed the KTP-1 based on a Soviet platform, and in 1977 a domestic production plant was set up, where 600 units per year could be produced. In the 1980s came the KTP-2 and the number of harvesters rose to around 4,000 machines in 1990. The KTP machines were of great economic importance; previously the harvester fleet was imported and paid for in hard currency. Now the machinery was built in Cuba, and used components paid for by the incomes from the lucrative Cuban-Soviet sugar trade. There were superior models on the market, but the lower efficiency of the KTP was set off by the foreign exchange savings (Perez-Lopez, 1991).

Industrialisation and diversification improved over time, and in the 1980s 70% of machinery and equipment for the sugar industry was produced in 11 metalworking factories in Cuba. Cuba also developed capabilities to export sugar mills, and in the 1980s Cuba participated in setting up a mill in Nicaragua, where they supplied designs, supervisory personnel for construction, and machinery and equipment (Perez-Lopez, 1991). By the 1980s, the problem was more suitable lands, rather than adequate machines, that prevented further expansion of mechanisation. By 1989/90, an estimated 63% of CPA cane was cut by machines and 26% of private, non-CPA grower cane. Furthermore, CPAs began to have their own harvesters; by 1990, CPAs owned 560 combines, whereas before 1980 the state owned and operated all harvesters, and would harvest the CPAs lands on contract.

However, mechanisation is not completely unproblematic and purely positive. There are claims that a great problem behind the low yield in Cuban sugar production is that the mechanised harvesting generates too much waste (Perez-Lopez, 1991).

For long periods of the time, the topic of the sugar industry was largely a matter of restructuring and downsizing. In the last few years, however, there has been a somewhat more optimistic view, even though the hurricanes seem to have caused serious damage and the last few harvests have been

disappointments. There are plans of restarting operations of the sugar by-products plants (Cubaheadlines, 2009). Something that is also emphasised as important in the discussion papers for economic reform. There have been new partnerships with foreign partners and the Sugar Ministry has created a company, Zerus, to sign joint ventures. Zerus has expressed interest in joint ventures to produce sugar, syrup, ethanol, alcohol, energy and other derivatives. An obstacle in this process is the US Helms-Burton law, which penalises investment in US expropriated properties.

Furthermore, when the Cuban internal production system collapsed, technicians started to look abroad for new opportunities. Cuban researchers began developing integrated control systems for mills and plantations in booming Brazil and other South American countries (Kerr, 2008). One of these outcomes is the Techagro, a commercial arm of a consortium of Cuban and Brazilian universities and research bodies. The partner from the Cuban side is the Cenpalab, a Cuban Laboratory company. There is a regional head office in Brazil, in Aracatuba, with further small regional offices, with 2,000 employees in Brazil, Cuba and Chile. A majority of the employees are Cubans, consisting of university-trained graduates in mechanical, electrical and electronic engineering, GIS-computer specialists and programmers. They sell services directly to mills, but also to machinery manufacturers that incorporate their technology as value added (Kerr, 2008). One of their products and services is to provide precision agriculture technology, through which firms can collect data to monitor yield and distribution, and there is development of automatic base-cutter systems and harvester performance reporting. They also offer to send out Cuban technologists to work in different localities to implement, test and adapt equipment (Kerr, 2008).

It is commonly argued that Cuba has a great potential in the availability of skilled knowledge workers, which could be used in the future for a diversification of the economy in to high-productivity trajectories, and that it is mostly current misuse by government planners that prevents such a development (Monreal, 2004). However, there have also been arguments that the Cuban labour force is unbalanced (Llocay, 2004). As there have been other types of governance mechanisms for managing production arrangements, other skills have been developed. If the Cuban economy were to transform into having more market-based or decentralised arrangements, there would be a greater need for business administrators, marketing and

sales personnel than what is currently available. Llocay (2004) have explored the distribution of skills and occupation in Cuba and found that this differs greatly from market economies. Cuba has a high percentage of majors in education, health care, and physical education, which together accounted for nearly 70% of post-secondary students in the 1990s. On the other hand, Cuba has a very low percentage of business students.

Decisions are and have been much centralised, and initiatives for upgrading and innovation come from central authorities. In Cuba politics is responsible for societal development – or the lack of it. During the time of this project, there have been quite radical shifts in the political interest in the sugar industry. First there was no interest in the industry, as it was seen as an industry of yesterday and not for the future. Then there was renewed interest and in particular for sugar as biofuel. To be followed by a denunciation of sugar cane based ethanol for energy, the central political position was to oppose the interest in the US and EU of biofuels; to the current interest as expressed in the latest programme for reform, where the production of ethanol, food and electricity is emphasised.

4.10.4.4 User-Producer Learning

All sugar production is purchased by the government and prices are decided by the public purchasing board. There are possibilities to sell some agriculture products on private markets, which are of greater interest to individual farmers, as the prices are better and there are possibilities to earn convertible pesos. Even though the government buys all products, it uses the demand function less, as a tool directly for influencing production. These decisions are rather pushed from the supply side by political initiatives. Still, the relatively low prices paid for sugar indirectly have a negative procurement effect that gives farmers incentives to concentrate their efforts in the free markets and in the informal industries.

Despite being a highly co-ordinated economy where local user-producer learning could easily be undertaken, national and international linkages appear to be more important in Cuba. The economic development in Cuba has always been dependent on foreign links in the sugar industry, first with Spain during colonial times, then the special relations with the US that offered special quotas and prices for Cuban sugar producers in return for favourable conditions in providing mechanical equipment, regulated by the Jones-Costigan Act of 1934 (Pollitt, 2004). This agreement favoured the

production of raw sugar in Cuba and Cuban import of machinery from the US. The agreements favoured both Cuban firms and the growth of the cluster vis-à-vis other countries' firms, but at the same time it created a disadvantage against potential Cuban mechanical firms. This hampered the production of local machinery (Pollitt, 2004). There were some independent foundries, and most mills had some metal-mechanical capacity in the mill, but 80–90% of the capital goods still came from the US (Perez-Lopez, 1991).

After some initial challenges up until the 1970s, the sugar industry grew in the 1980s. Despite economic problems in the Cuban economy that began already in the mid80s that were countered by rectification processes, where more centralisation was introduced, the sugar sector kept on developing until the advent of the Special Period. The relation with the USSR was very influential in this growth; from the USSR Cuba received subsidised prices for fertilisers and mechanical equipment and additional high prices for their sugar production, as well as long term credits at low interests (Brundenius, 2002). This led to an extensive model, which advanced the amount of land used for sugar production and increased fertilisers and mechanical equipment. The relation provided resources and enabled upgrading, but sometimes it delayed industrialisation processes as the local industrial linkages were still disconnected. Cuban-Soviet collaboration led to the introduction of a Soviet-built loader, the PG 0.5-CT, and in the same year, 1963, Cuba and the Soviet Union reached an agreement on mechanisation of sugarcane harvesting. Cuba imported large numbers of harvesters from Soviet, and the domestic process was abandoned. Then they came to try to design the machine in Cuba, but built it in the USSR on the basis of a Soviet platform, due to Cuban inexperience and the Russians' lack of knowledge of sugarcane conditions the development took time. Out of this collaboration came two types of machines that were imported for the harvest of 1965, which did not work very well in Cuban conditions. It took some time, but by the mid 70s the problems were overcome. By 1977, Cuba mass-produced a Cuban harvester called KTP, a Cuban-designed machine based on a Russian platform, and initially produced in a Russian-built factory in Holguin. Edquist (1985) came to the conclusion that the lack of local linkages, and Cuba's choice to work with the Soviet Union instead of an experienced partner, led to a loss by not implementing superior technology, and a delay by five to eight years of proper mechanisation.

At the end of the 1990s and the beginning of the 2000s, a new international actor appeared on the Cuban scene, Venezuela. However, this time the exchange is less within the sugar industry, but more an exchange of medical doctors, sport trainers and teachers, for subsidised oil. It is estimated that Cuba receives oil to the value of around USD 2 billion in exchange (Robles and Dudley, 2006). In 2006–2008 there was a drive to revitalise the infrastructure of the industry with the help of Venezuela, with a programme to upgrade a number of mills, roads and railways, and increase the use of fertilisers and harvesters (Robles and Dudley, 2006). Together the two countries have also embarked on setting up state-driven sugar refineries in Venezuela. Cuba exported eleven old sugar mills and technology for the derivatives industry, especially for producing animal fodder (Grogg, 2008). Within the ALBA framework (the Bolivarian Alternative for the Americas)²⁰ there have been bold plans to build 11 mills with ethanol capacity in ALBA countries (Frank, 2009). This could mean a boom for the machine-building industry in the Vila Clara region, which built eight sugar mills between 1965 and 1985. Whether this project will begin or is mere rhetoric remains to be seen, though. In Venezuela projects have been initiated for the building of large Cuban-style sugar agro-industrial complexes, such as the Ezequiel Zamora Agro-Industrial Sugar Complex based on material from the reduced Cuban sugar mills. However, it seems that there have been great problems in implementing the sugar factories in Venezuela. Whether the problems are due to Cuban or Venezuelan actors is unclear, however. The USD 200 million CAEEZ project, in Venezuela's president Chavez's home state Barinas State, has so far not been very successful (El Universal, 2008a, 2008b). Furthermore, Venezuela is experiencing great economic problems of falling oil prices, and a shrinking local economy, which makes it questionable whether these projects will be carried out in the near future.

International linkages are still very influential, and another important factor for the development of the Cuban economy is the American economic blockade of Cuba. This reduces the opportunities to export to a large market that is close by and which has great potential for Cuban firms. Cuba's close location and also relatively close location to both the US and the EU (which

²⁰ ALBA consists of Venezuela, Cuba, Ecuador, Bolivia, Nicaragua, Dominica, Antigua and Barbuda and St Vincent and the Grenadines.

will open its borders for sugar in 2012), together with its beneficial climate for sugarcane, could be a really good opportunity for sugar and ethanol.

There is also a reappearance of old international linkages. Old contacts from the former COMECON that are now recuperating economically are once again seeking collaboration (Cubaheadlines, 2009b). For example, Cuba's Industrial Machinery Group (GIMAC) has exported three modified sugar harvesters to Russia, where they will be used to harvest sorghum. The units were co-developed with Russian university researchers and will be used by Russia's Slaviansky Agroindustrial Complex.

4.10.4.5 Joint Action

As the state dominates activities in Cuba, a large proportion of the activities being carried out could be considered joint actions. Cuba has also over long periods of time carried out activities to develop the industry, with ambitions of upgrading and innovation. One of the first measures after the revolution was also to diversify the industry, and to try to break out of international trading networks and to substitute imports with the country's own national production. The first efforts that was an attempt to move away from sugar production was not successful, but the ensuing efforts to develop and upgrade the sugar industry did.

State arrangements facilitated in breaking a previous inertia, whereby Cuba was more oriented towards pure sugar production, with fewer producers of metal-mechanical equipment and also little locally developed science and technology. As mentioned above, production was upgraded with mechanical harvesting, an increased use of tractors and fertilisers as production input, with figures as high as in US production (Nova Gonzalez, 2006; Fernandez Dominguez, 2006).

However, the long-term sustainability of previous practices can be questioned. When the USSR collapsed, Cuba's favourable price levels and long term credits disappeared and subsidised fertilisers and mechanical equipment disappeared, resulting in a contraction of the sugar economy.

There have been a number of rounds to restructure the industry in order to revitalise it, but so far the results have not been strong. Unlike in other countries, there has been little effort to support small entrepreneurs to expand their own firms. Rather, there is restriction on the growth of small firms. Business development can be seen as following two lines after the

Special Period began. One is to allow small firms to develop in order to survive, which is more a type of subsistence entrepreneurship. Then there are some efforts in prioritised industries, such as biotech and tourism. There have also been some efforts to reinvent the sugar industry, but these have been more centralised efforts.

In an effort to manage the restructuring of the sugar industry and to handle sub-employment and unemployment, by trying to restructure and upgrade the Cuban labour force with educational programmes, a major programme for re-education has been launched. Education has been expanded, especially at university level, where enrolment increased 172% in the period 1989–2007. The efforts have been geared towards humanities and social sciences (3.360%), medicine (1.131%) and teacher training (724%), whereas the levels were more moderate in other areas such as agriculture (12%) and in technical fields (27%), and there was a fall in natural sciences and mathematics (40%) (ONE, 2007). Part of this expansion is the launch of the Municipal Universities (SUM) that offer a number of courses given at local universities evenly spread out in some 800 localities around the island, and in some places these provide training that is relevant to the needs for the sugar industry (Martinez 2008; Caballero, 2008). In 2007/2008 there were 744,000 students enrolled in institutions of higher learning (Brundenius, 2009). The labour specialisation is more driven by a supply-side perspective than a labour-demand perspective, and there has also been an over-production of capabilities that are not being put to use, since there are not so many jobs for social scientists; for this reason there was a cut in attendance rates of 86% for the year 2007/2008. Due to this mass-scale programme there have been great quality problems, as there is a lack of teachers. Many former teachers and doctors have left their professions as the salaries have been too low and sought employment in tourism-related activities (Mesa-Lago, 2008). There are also many teachers and medical personnel employed in Venezuela, in the exchange programme of Cuban professionals and Venezuelan oil.

As the government controls most aspects of the activities that are carried out in Cuba, they can amass resources to start programmes for retraining and also to provide social programmes to cater for people during these programmes. When mechanisation was introduced in Cuba in the 1960s, there were few protests compared to pre-revolution times when the trade unions objected to many productivity-enhancing practices if they threatened

labour opportunities. Of course, there was an increasing labour shortage and labour unions and employment opportunities were controlled by the party. Still, the introduction of social welfare programmes and opportunities for reskilling reduced the opposition to innovation and upgrading among labour (Edqvist, 1985).

At the same time the interests of the party blocks all other initiatives, and through the control of the state apparatus prevents innovations that do not work in line with central opinions. Sugar has a historical colonial heritage and has always been at the centre of the Cuban economy. In political terms it symbolises a negative past which it is desirable to move away from, best exemplified by another quote from Fidel Castro: *“Sugar belongs to slavery times and will never come back to this country”* (Mesa-Lago, 2005). At the same time there is a lot of interest from different actors, within ministries, the industry and at universities (Alvarez Delgado and A. Torres, 2007) and foreign interest in reviving the industry (Rodriguez, 2007).

The political sentiments about sugar are creating lock-ins to the possibilities to develop the industry. There is political rhetoric that Cuba wants to move away from sugar and stay away from sugar. At first there was official Cuban interest in developing ethanol for energy, and discussions with Venezuela for joint development. However, after the US and Brazil formed a partnership to stimulate ethanol as a biofuel and try to develop international commodity markets, strongly negative messages were communicated by official sources (Carroll, 2007). At the same time, as has been mentioned above there are other actors that are interested in revitalizing the industry.

There are rigidities in the system that to some extent are being addressed as this thesis is being written; at the same time, there may be a need for even greater changes including an even larger role for market-based arrangement and private decision making. However, many of these measures cause conflicts within the political apparatus, which has great ideological objections to these types of measures (Mesa-Lago, 2008). As was mentioned initially in this section, there is however a large number of measures proposed to revitalise the economy that includes a number of these reforms.

4.10.5 Summary of Cuba

State arrangements dominate the Cuban economy and set the limitations for the scope of the other arrangements. The state arrangements restrict the

other arrangements, whose presence is much lower than in the other cases. There are also quasi hierarchies and to some extent market and network arrangements, even though these are possibly more influential in the informal economy and are not strong driving forces for innovation in the sugar industry.

For innovation in Cuba, cluster externalities matter less, as innovation is more driven by national and international relations. National research centres and co-ordination through ministries have been more important for enabling specialisation, joint action and knowledge spill-over than local bottom-up initiatives of local informal knowledge spill-over, specialisation, user-producer learning driven by competition and collaborative networks. Markets and networks have played minor roles for clusters, and most influences come from state arrangements, with some importance for quasi hierarchies for coordination of local activities and for diffusion of innovations and knowledge. Possible market influences come from international relations.

As the state dominates activities it is of key importance that it creates opportunities and resources for production to take off. In the period 1970–1993, state arrangements succeeded in upgrading the sugar industry, building up a strong science and technology base with knowledge of how to produce a number of derivatives, and developing proper production of mechanised harvesting equipment. International linkages were important in this process.

At the same time these relations contributed to fostering non-sustainable practices as Cuba received much higher prices for its sugar than from world market, and also subsidised prices for input factors in the production. When the Eastern European markets were changed, the Cuban production model was also challenged when the cost/profit structure of previous practices was unsustainable. State arrangements in Cuba have enabled upgrading of the sugar industry, but the will of the state is not always enough, as the examples of the political campaigns like the *Los diez millones de que van ... van* campaign and the attempts to spurt production at the beginning of the 1990s and around 1997. Cuba is a small country with limited resources, where political coordination and prioritisation of industries prevent many flowers from blooming and limit the opportunities to be successful in many concurrent industries.

When it comes to externalities normally attributed to other kinds of arrangements, in the case of Cuba these are strongly affected by state arrangements, and it is mainly state arrangements that enable cluster externalities. There is labour specialisation and division of labour within the sugar industrial complex, and knowledge spill-over taking place in the cluster, but not driven by market incentives or networks enabling knowledge diffusion. Because there is little space for individual decision, there are few incentives and scope for the development of bottom-up innovations, and the lack of markets means poor practices are not weeded out.

The industry has been downsized and restructured, and part of the labour force has been retrained for other areas through massive higher education programmes. Since the Special Period most production has been carried out on non-governmental farms. In locations where there have been more individual incentives for farmers, productivity has risen significantly (Alonso Pippo et al., 2008). However, the incentive schemes and scope for activities do not favour the production of sugar cane, which is falling, and farmers' activities are increasingly geared towards other areas. This is an outcome of a number of conflicting state arrangements that creates negative incentives for the sugar cane growers, which in turn affects all other parts of the value network around sugar.

There is a problem in the production of the primary goods, due to low incentives. Since prices are centrally set and the prices offered are so low that there are no incentives to increase production, even though world market prices has risen, the prices paid to the sugar farmers have not risen at a corresponding rate (Nova Gonzalez, 2006, 2010). The incentives and possibilities for agricultural sector are aggravated by the dual currency system, with low incomes for farmers in the national currency, but high prices and need for convertible currency to purchase supplies. Many farmers are instead geared to activities where they can earn convertible pesos, as this is vital for acquiring supplies for production, and also for everyday life.

Another problem is the lack of market mechanisms that sort out poor practices. It is very common for Cuban companies to have debts, and many of the UBPCs that are the most inefficient co-operatives are heavily indebted, as firms cannot go bankrupt. The debts from co-operatives to the government are amassing and the total amount is substantial. This is something called the chain of non-payment, where not only UBPCs but all

firms neglect payments, which makes it a problem to pay other firms. Total debts in Cuba amount to around 20% of the GDP (Dominguez, 2004). This system removes incentives to improve poor practices.

The sugar industry has been dwindling since the 1990s. There seem to be organisational problems, challenges with the incentives infrastructure and resource allocations, as well as a long-term policy ambiguity towards the industry. Depending on the will of the government, the industry can develop. The country has infrastructure, land, scientific and technology capabilities, skilled labour and a potential domestic market for ethanol. There is also great potential in international markets, with growing demand in Russia and China, Nova Gonzalez (2010).

Centralisation and planning can enable scientific and technological capabilities and build up resources. Yet political will is not the only factor for success, and a lack of a market limits potential benefits from it, with fewer opportunities and less space for innovators to try out ideas in their areas of interest. Entrepreneurs and firms cannot decide what to produce and therefore cannot respond to opportunities; also, with the lack of price mechanisms, it is hard to understand what is important to produce, and also what needs to be improved in order to increase efficiency. Hence there is also less incentive to pick up new technologies to improve processes. There are also limitations for whom an actor can collaborate with, which affects the opportunities for new innovations to occur. There have been some reforms of the agricultural sector, but allowing for more market and network arrangements would be a key to revitalising the sector.

In recent years, most of the patents in Cuba have come from the biotech industry, originating in Havana's Bio-Tech pole. Some of these products and methods are related to the sugar industry and are based on sugar cane as primary material. The biotech and pharmaceutical products are growing and are among major export earnings (Grogg, 2009). The industry began to develop in Cuba in the 1980s. It holds some 1,200 international patents and export sales totalled USD 340 million in 2008. Besides this, vaccine development has eradicated a number of diseases, e.g. polio, diphtheria, etc. In the work process there seem to be an emphasis on decentralised decision making and local collaboration (Thorsteinsdóttir et al., 2004). The institutions have been given some independence and incentive systems that reward innovation. Luis Herrera, head of the Centre for Genetic

Engineering and Biotechnology (CIGB), emphasises the importance of local networks and collaboration between institutes managing the full life cycle of the products from research to production and marketing (Grogg, 2009).

It is often argued in innovation studies that it is not short-term efficiency that guarantees long term competitiveness, but to be able to innovate. In the case of Cuba inventions and technologies have been developed, but due to inefficient organisation and lack of scope for individual initiatives, long-term productivity is not generated. The combination of innovation and efficiency generates productivity. An organisation or country can plough many resources into generating inventions, but without efficient organisation it will not be worthwhile.

Table 28 summarises the overall estimation of how the institutional arrangements in Cuba influence cluster externalities to affect innovation.

Table 28: Summary of institutional arrangements and externalities in Cuba

	Intense competition	Knowledge spill-over	Specialisation	User-producer learning	Joint action
Market	No	No	No	No	No
Network	No	No	Different types of co-operatives, but they have little independence	No	No
Quasi hierarchy	No	Diffuses best practices. Educates labour.	Some types of division of labour between the centre, sugarcane producers and other service companies	Some new input from foreign firms with special knowledge	Refineries decide product portfolio and also influence process decided by surrounding producers.
State	Reduces activity in formal sugar industry, possibly diverting efforts towards other industries.	Prevents new firm start-ups. Stimulates by extension services by institutes.	Mechanisation Creation of research capacity Extension services New cane varieties Training and retraining of labour Exportation of services	Interaction between refineries and research institutes, and between refineries and producers.	Upgraded industry. Social programmes overcame vested interests. Educated and retrained labour Blocks innovation, due to political ambiguity and vested interests. Political campaigns create a cognitive lock-in.

5. Comparative analysis

5.1 Connection between Arrangements and Externalities

Technology comes from the combination of the knowledge of how to control and manipulate natural phenomena to address certain needs (Arthur, 2010). Technologies can be combined to create even more complex technologies or to replace technology combinations in order to reduce complexity. Innovation is the matching and combination of technologies with needs, and with appropriate business models and production processes to carry this out. Innovation can come from the creation of new organisations or as new products and processes within existing organisations innovations or by collaborative efforts of actors creating new ways to organise activities.

Cluster externalities can influence these processes in a number of ways, through incentives, structures that enable or constrain innovation. The externalities have effects on how knowledge is generated, diffused and organised, both scientific and engineering knowledge and knowledge about needs. The institutional arrangements will affect how this takes place, by enabling or preventing the cluster externalities.

In each of the cases there have been different institutional arrangements in place that affect the cluster externalities. However, the presence and mix of arrangements differ between the cases. São Paulo has the greatest mix and influence of different arrangements and the greatest institutional thickness, and Cuba the least mix of arrangements, but with institutional thickness, whereas the North East has the least institutional thickness, in particular with less scientific capability than the other cases, but a greater variety of institutional arrangements than Cuba. In the cases the prevalence of externalities and their role for innovation have differed.

When comparing the cases one can observe that there are stronger connections between certain arrangements and externalities leading to innovation. Below is a presentation of the comparative findings of the cases;

some of these findings are elaborated upon in more depth in the following sections.

Markets are an institutional arrangement that works more through incentive signals than as an institution that enables innovation. In Cuba, this arrangement mattered little, as there are few market arrangements. In Brazil the role of the arrangement has increased since the deregulations in the 1990s and innovations among firms have increased. The strongest and most unique connection for market arrangements is with intense competition, as it provides incentives for innovation through rewards and punishments that pressure firms to innovate. Incentives and rewards for specialisation, which have increased since 1990 in Brazil, can also be conducive to innovation. There has been knowledge spill-over through labour rotation and new firm start-ups, which increased after 1990 in Brazil. User-producer learning is stimulated through allocation of resources to innovations that stimulate local learning, a strong driver in São Paulo, but lacking in Cuba. Market arrangements cannot enable collaborative endeavours of joint action, and there is a risk of constraining factors from causing under-investments in long-term research and causing congestion in the infrastructure and environmental problems, such as pollution. There have not been any indications of actors in clusters competing on a personal basis for social standing, as suggested by Porter (1998), yet knowledge is not blind; actors know who their competitors are, as suggested by Boari et al. (2003).

Network arrangements mainly influence externalities that enable innovation, but they influence incentives through reputation and access to networks, and can cause constraints through vested interests. They are suitable for managing uncertainties and the strongest connection is with joint action. They enable specialisation through technology development, as in CTC. Common problems are addressed, such as congestion in infrastructure and lack of skilled labour, e.g. APLA in São Paulo. Network arrangements enable knowledge spill-over, through informal personal networks, as among the millers in the North East and knowledge-diffusing organisations, e.g. ORPLANA. Specialisation is enabled through division of labour, as between Grupo JB and Pitú, and user-producer learning, like the networks in Piracicaba between Dedini, CTC, and Cosan. There is a potential danger of networks turning into cartels, furthering the needs of vested interests that constrain innovation by preventing newcomers or new technology. There were little indications of community-based networks, but networks were

more of professional character. The only observation is in the case of the North East, where it has had an effect on deliberating public goods, by restricting competitive pressures to upgrade and mechanise harvesting on sugarcane farms. Networks have been important in Brazil and in particular in São Paulo, whereas they have been less important in Cuba.

Quasi hierarchy arrangements work through externalities that enable, constrain and provide incentives for innovation. The strongest connection is with knowledge spill-over. Dominant firms are stronger in knowledge development that is diffused in formal relations to suppliers, e.g. Cosan and sugar cane providers, and in Cuba with refineries and co-operatives. Knowledge is also spun out in new firms, like Technopulp Ltd. It enables user-producer learning, through suppliers that pick up practices from dominant firms, through dominant firms serving as testing grounds for the small firms and through small firms piggybacking on dominant ones to reach markets. Quasi hierarchies can also be positive for specialisation, through outsourcing that stimulates division of labour, e.g. Dedini and smaller local metal-mechanical suppliers. Dominant firms are influential for joint action in getting a critical mass behind collaborative projects, such as Uniduto logistics. There can be complementarities where joint offers can be created between large firms with volume products and small firms with specialised marginal products, e.g. Smar Equipamentos Industriais and DLG Automação Industrial. This can constrain innovation, by preventing newcomers and new technologies. Dominant firms are important as resourceful actors implementing innovations and developing technology for their own purposes in all the cases, but as the North East is less diversified with fewer actors in place, the dominant firms become less important in stimulating other firms to innovation, whereas they are more important in São Paulo and Cuba for knowledge diffusion.

State arrangements can both create incentives and influence externalities to enable and constrain innovation. The strongest connection is with joint action and specialisation. Joint action addresses problems of lock-in, congestion and infrastructure issues, such as through Pró-Álcool and APLA. Specialisation is enabled through the provision of research and education, e.g. Planalsucar/RIDESA, Cuban research Institutes, by providing specialised services, e.g. standardisation and metrological services, and through financial support to business development, e.g. SEBRAE and BNDES. State arrangements enable knowledge spill-over, through support

to new firm start-up and financing of linking platforms, education and research, and they can also be positive for user-producer learning, through procurement and regulation. They can be negative for intensive competition, by regulation and protective measures and can be caught by vested interests that prevent newcomers and new technologies, or as in Cuba where there is political distrust of the sector and conflicting political interests that prevent innovation. State arrangements can enhance congestion problems and lock-in, by creating incentives and providing support to expand sectors over sustainable levels, as has taken place in both Cuba and the North East of Brazil.

A summary of identified relations between institutional arrangements and cluster externalities in the cases is presented in Table 29.

These relations between arrangements and externalities are more pure ideal types, and when observing the cases over time, one can see that the influence of the different arrangements alters over time. The state is the dominating arrangement in Cuba, but there are also quasi hierarchies, and some networks and market arrangements, the latter two having little influence in the formal economy. There is currently an increased role for markets, and there have previously been tests with increased scope for family firms. The outcome of this has not been innovations in the sugar cluster, but rather a diversion of efforts away from sugarcane farming to other activities where convertible currencies can be earned. In Brazil the state is very influential, it used to be even more influential, but its role has changed, from more direct interventions with the intention to steer the industry through the IAA institute, towards a role of a facilitator that builds capabilities and co-creates opportunities, such as the creation of research programmes, loans for upgrading of firms, deliberative industry programmes, lobbying international markets and perhaps most importantly, the creation of local demand through legislation on mixing petrol with ethanol. The role of market arrangements has increased over time, and networks and quasi hierarchies were always important. However, the direction and purpose of networks have altered over time, more so in São Paulo than in the North East. Networks have influenced and co-operated with state arrangements for industry renewal (Pró-Álcool and Planalsucar), but have also influenced state arrangements to provide protection and subsidies. Since 1990 networks have been more geared to creating joint opportunities, but in the North East they

are still to some extent more oriented towards protection of established actors.

Table 29: Indications of institutional arrangements and cluster externalities

	Intense competition	Knowledge spill-over	Specialisation	User-producer learning	Joint action
Market	Provides incentives for innovation. Not personal rivalry, but knowledge of rivals. Can constrain through congestion in infrastructure and R&D.	Enabling through labour rotation. Enabling through start-ups.	Incentives to increased specialisation and division of labour among firms, research institutes and labour.	Generate resources for innovation and input for resource allocation. Pressure to certificate Start-ups, benefiting from complementary firms.	Not enabling joint action
Network	Has created problems of vested interests preventing newcomers. Community concerns have blocked upgrading.	Enable spill-over from informal and formal networks, between researchers and industry, and between industry actors. Created knowledge that has been spun out	Enabling through networks that provide specialised services & carry out research. To some extent enabling division of labour among suppliers, as in APLA.	Professional networks enable technology development. Particularly important for more uncertain processes.	Address problems of inertia and lock-in, e.g. new technology creation, infrastructure and lobbying. Organisational innovations such as price negotiations in Consecana.
Quasi hierarchy	Incumbents have prevented newcomers in the sugar industry through connections with state arrangements.	Dominant firms develop and import new technology, diffused to suppliers and through informal networks Spin-offs from dominant firms.	Division of labour through outsourcing. Between refineries and specialised services in Cuba.	Dominant firms serve as testing grounds SMEs piggyback on dominant ones to reach markets. Mills demand new technology	Influential, due to resources and power. Mills are co-developing with universities and suppliers. Complementarities of marginal and large-scale volumes of small and large firms.
State	Can constrain or enable competition by preventing incumbents from blocking newcomers Can stimulate herd behaviour	Enable knowledge development and diffusion through universities and institutes, and financing of activities in institutes In Brazil support to start-ups, Enable networks, e.g. In Cuba develop and diffuse knowledge, through institutes and ministries, but prevent through prohibition of new firm start-up.	Enable specialisation of labour through education and vocational training. Support to specialisation of firms, through research and firm upgrading. Provides specialised services, increasing division of labour, e.g. standardisation. In Cuba, through mechanisation, research capacity, extension services	Enable user-producer learning through public procurement of ethanol and give incentives through legislative requirements. Enable through interaction between public service providers like research institutes and mills Can improve complementarities by service provision, such as venture capital	Carrying out activities to remove constraints such as lock-in, by investments in basic science, education, reskilling and in infrastructure. System level innovation. Deliberative projects such as APLA, technology roadmaps, and financing schemes that stimulate collaboration. In Cuba also blocking innovation through political vested interests, blocking some types of changes and new firm creation.

State arrangements are being influenced by market arrangements and the forms have been altered to match market logics, such as research and innovation funding not being provided to targeted winners, but awarded to research proposals through open competition (e.g. Banco do Nordeste research funding). At the same time there is also, as mentioned, above a network influence in which private actors and state co-create policy and

research programmes (e.g. FAPESP programme in São Paulo, both together with Dedini in exploring sugar industry challenges, and through industry-wide technology roadmaps). Even though market arrangements are more important today, the indications in the empirical material are not that they dominate the other arrangements, as state arrangements are doing in Cuba. Beyond the local/regional scope, global market arrangements are very important and hard for individual countries and national state arrangements to ignore or dominate, and they influence the clusters. Cuba has less access to world markets and greater problems in acquiring inputs, due to the US blockade, Brazil has pursued strict macroeconomic policies in order to build confidence in international capital markets, which has created a situation of high interest rates in Brazil that have been a problem for firms with an ambition to grow as it has been hard to acquire capital. On a smaller scale, Brazilian sugar refineries are carrying out certification schemes in order to satisfy international consumer demands for corporate social responsibility.

Institutional arrangements are more strongly connected to some of the externalities than others, which relate to the degree to which the institutional arrangements are more effective for incentives, enabling or constraining innovation. At the same time the institutional arrangements and the externalities can complement each other, and contribute different input to innovation processes. The development of new technology comes both from the combination of existing technology modules, and the combination of different ways to control natural principles to meet different needs (Arthur, 2010). In locations with a richer set-up of institutions and institutional arrangements, it is likely that greater variety develops in knowledge and technology. With a variety of arrangements in place, there would be more channels for diffusion of knowledge about different types of need, as well as a broader variety of potential technology components that could satisfy these needs, and means for organising innovation activities. Arrangements differ with regard to how they provide incentives, enable or constrain innovation or can overcome constraints, and therefore they can be complementary. Different time horizons, resources and activities are possible. As an example from our cases, the state can be important in generating basic scientific components, e.g. Planalsucar and RIDESA. However, this has also been taken care of by networks like CTC and private actors like Cana Viallis, while their focus has been slightly different and the competition between these actors and arrangements has provided a broader

knowledge base. These different actors have responded to different demand signals, as needs have been formulated to them. Furthermore, the knowledge is also diffused differently depending on the forms. The needs can be satisfied through different arrangements, such as market demands, public procurement for goods, but also through networks and quasi hierarchies that also shape the way in which activities are carried out. Markets and state arrangements are more rigid and networks and quasi hierarchies can allow for looser management of innovation processes which are better adapted to more uncertainty, such as the development of bioplastics. For the development of this technology, scientific knowledge has been accumulated through research in state-financed universities, scientific and engineering solutions have been devised in CTC, through network and state financing. The technology has been financed and co-developed between CTC and refineries. Together they built a pilot unit that was located in the refinery. Through this user-producer process they received important input on necessary requirements, which was used to refine the final product. More engineering-oriented skills from publicly financed universities became involved. The technology has been picked up by a spin-off company, PHB Industrial S/A, that is commercialising the product. To conclude this argument, with a greater number of types of arrangements in place, more complementary processes are enabled that benefit innovation. A cluster with more different arrangements and institutional thickness would thus be a more conducive place for innovation.

Of our cases, São Paulo is the one with the densest and most diversified presence of actors and with all types of institutional arrangements in place. It is also the most innovative case. Cuba has a broad set-up of actors, but mainly state and quasi hierarchy arrangements, and the North East has a thinner institutional set-up and fewer local networks. My understanding of this is that in São Paulo the arrangements in the cluster are better at generating new knowledge that is better adapted to local needs, and that institutions and arrangements are better at generating and channelling knowledge about technologies and needs and possibilities for combining these.

The contrary case is a monoculture of arrangements, which ought to be negative for innovation. Innovation needs a mix of knowledge bases, such as scientific and engineering knowledge as well as more practical and hands-on tacit knowledge, such as organisational and market knowledge (Scott, 1998).

Innovation needs interaction between these knowledge bases. Scientific knowledge in itself mostly cannot be used by itself in practice, but needs to be combined with engineering or hands-on knowledge to adapt it to practical purposes, and for innovation it has to be combined with knowledge of organisations and markets. In Cuba there have been problems when central decision making has tried to forcibly implement scientifically based practices, but without any arrangements in place where hands-on knowledge or engineering objections could oppose and block the ideas, as during the *Van Van* campaigns of the 1970s. Likewise there is a danger that if only markets prevailed there would be no mechanisms for creating social innovations to address common problems, or there could possibly be under-investment in long-term knowledge, such as basic science. Networks and quasi hierarchies could turn into rent-seeking networks that would prevent newcomers and new technology.

5.2 Market Arrangements – Pressures to Innovate and Price Signals

Market arrangements have the strongest connection to intense competition of the cluster externalities, but are also very important for specialisation and knowledge spill-over. As Brazil has implemented more market-based arrangements, specialisation and division of labour have grown and the speed of innovation is increasing. In Cuba the lack of market arrangements is creating incentive problems, with low efficiency and constrains for innovation.

The role of market arrangements in Brazil has increased since the reforms in the 1990s, and as a result there is higher competitive pressure. There is a greater pressure on firms to innovate to survive and the number of innovations and indicators of innovativeness is higher since 1990 than before. At the same time, there has been turmoil in which a great many firms went out of business, due to cost ineffectiveness. There has also been extensive relocation of firms, moving from the North East to the South.

Market arrangements are and have been stronger in São Paulo than in the North East, and there are more innovations coming out of São Paulo. São Paulo, however, has a stronger local market and a more diversified institutional set-up, with suppliers and actors seeking out different niches.

There are producers of machinery and equipment, consultants, R&D institutes, but also sugarcane production and sugar producers, with the entire value network present. Even though there is a strong process of mergers and acquisitions in the industry (Zylberstajn, 2006), there is also a process whereby the sugar mills are increasingly outsourcing and breaking up the organisations. In recent years specialisation has increased; there are any more firms and in more specialised niches, such as the company BUG specialising in pest resistance (Da Silveira, 2008), new plastic companies like PHB (Molinari, 2006) and the cane companies Cana Viallis and Allelyx which provide consultancy services to sugarcane producers. Olivério, the vice president of Dedini responsible for technology development, when asked what drove Dedini's successful growth, said that it is the market demand that has changed, and it is not due to industrial policy, technology or foreign trade (Inovação Unicamp, 2007).

Restructuring after the 1990s have been tougher in the North East than in São Paulo, but the remaining firms and institutes in the North East are innovating and have increased their productivity. In the North East there is also some specialisation, but the metal-mechanical industry is relatively modest and there are fewer institutions. Many of the specialised suppliers that are located in the North East have their head offices in São Paulo but have a local branch office in the North East, like Dedini.

With increased specialisation and denser labour markets there will also be more opportunities for labour to specialise and raise productivity. São Paulo has the most qualified labour pool, and since 1990 skills has been increasingly specialised and there is also a greater availability of more skilled labour, even though the high demand creates shortages on occasions (Santos, 2008). Cuba, despite a lack of market mechanisms, has a specialised labour pool and has more specialised labour than the North East of Brazil, due to state arrangements for education and upgrading of the labour force. The North East has the least skilled labour force, and the labour market is also shrinking, while there is simultaneously a lack of semi-skilled labour, much needed for mechanisation to take place (Almeida, 2007).

Foreign firms are locating in the Centre South of Brazil due to the beneficial natural conditions, but also to acquire knowledge in the form of labour and technological suppliers. São Paulo has a thick, dense and diversified labour pool, for sugarcane production, sugar production, but also for metal-

mechanical industry, and with advanced skills in research and engineering. It is easier to find the right competences in Piracicaba than in other regions, and therefore relatively easier to initiate innovative projects there. A number of international firms intend to locate in Piracicaba with the specific purpose of innovating, and for this purpose they are interested in local knowledge and the local labour pool, e.g. Novozymes. The CTC research centre located in Piracicaba is receiving an increasing number of members that seek new technology to improve their processes (T. Andrade, 2008). The influx of these foreign actors will also mean an influx of new capabilities and knowledge to the cluster, further strengthening the institutional thickness.

The international demand for biofuel and the removal of trade protection in the EU for sugar have increased interest among international actors to invest in Brazil, such as Luis Dreyfuss investing in Crystalsev. The growing global markets for biofuels and ethanol have increased mergers and acquisitions among actors to take a strong position to address global markets, as with the Cosan and Shell joint venture.

From the cases there are no indications of actors competing on a personal basis for social status or that the transparency in production circumstances is affecting the pressure to innovate. Respondents did not acknowledge competing on the basis of social status (Neto, 2007; Almeida, 2007; T. Andrade, 2008; Sartori, 2008). If there is any type of social competition or group rivalry, it would rather be between actors from the North East and the Centre South. At the same time, competition is not blind and the actors are aware of which actors they compete with (Neto, 2007; Almeida, 2007; T. Andrade, 2008; Sartori, 2008). Respondents also indicated that after 1990 there was less informal exchange due to what was experienced as increased competition (Neto, 2007). In Piracicaba the creation of APLA had led to greater familiarity among cluster actors and increased informal collaboration (Castelar, 2008; Sartori, 2008). At the same time, general market trends and alterations in business cycles seem very important, as good times create opportunities for collaboration (Santos, 2006, 2008; Sartori, 2008) and recession increases the perception of competition.

In Cuba there are some market arrangements in free markets and informal markets. Free markets have been more tolerated in periods of economic problems, and as a way to increase productivity in agriculture (Brundenius, 2002). So far market-based arrangements have had little impact on

innovation, as individual firms have been limited in how they can alter their product portfolio and processes (Martinez, 2008). Likewise, firms cannot employ or fire labour, meaning that market signals do not influence resource allocation to innovations. Currently there are changes taking place, allowing for more individual small firms that will be allowed to employ and carry out activities more freely in a number of areas (the Economist, 2010c) and for more decentralised decision making (PCC, 2010). The outcome of this process is too early to predict, however. Market arrangements have had some effects on specialisation in the sense that some farms are diverting their focus away from sugar cane production.

Start-ups are important channels for innovation, in the form of spin-offs from established firms, university spin-outs based on new technology developments, joint ventures between established actors or completely new firms based on identified market needs. Fewer restrictive regulations and practices that prevent start-up of companies are better for knowledge spill-over. The easier it is to start new firms based on new knowledge, the more innovations may be expected.

Small firms are important for innovation, as they can have a greater scope to create more radical innovations as their range and focus of activities are easier to alter than for large ones. In Brazil, large firms are more innovative in relative numbers, but in absolute numbers there are more innovations coming from small firms, including more innovations that are new to the market. Small firms can also be the result of spin-offs from large firms, and an important channel for innovation to take place. Small firms are important due to their numbers and the fact that they initiate a multitude of new activities. The number of small firms is also growing, and quicker than large ones; in 2000 there were 47,082 small firms and in 2008 there were 65,049, a growth rate of 38.1%. The number of large firms has grown in the same time from 1,360 to 1,804 firms, a growth rate of 32.6% (IBGE, 2002, 2010).

Before the 1990s, there were not so many new firm start-ups in Brazil; there was more of a process of company growth and consolidation in the industry, where industrial policy focused on strengthening the large firms (Meyer-Stamer, 1995). Since 1990 in São Paulo, the sugar industry has grown with more active firms (Vian et al., 2006), and there is an increase in a number of new types of firms, such as new consultant organisations, and private R&D

institutes (da Graça, 2006). Start-ups have spun out of established organisations, firms and research institutes like Allelyx, Cana Vialis and Scylla Bioinformatica. These organisations also recruit from universities and other firms, further enhancing knowledge spill-over. Cana Vialis recruited a large share of its employees from the RIDESA programme (Simões, 2007b).

It is easier to find the right competences in Piracicaba than in other regions, and therefore relatively easier to start a new firm, or expand one's business there. It is also close to the city of São Paulo, with strong financial markets. There are plenty of examples of new firm start-up based on new knowledge spill-over, but also of established firms picking up on new knowledge development that is being put into practice as innovations. These would probably not have arisen in previous periods, as it has become easier to start new firms, based on science and technology. Today it is easier to find venture capital and for service providers to sell services and new products in the sugar industry (da Graça, 2006). Furthermore, existing firms are seeking out new processes to improve efficiency, e.g. biological pesticides and also new products to offer, such as car fuel and electricity.

Also periods of recession can stimulate innovation; when firms go bankrupt some parts are picked up as a basis for new firms. In the municipality of Sertãozinho in São Paulo there are plenty of examples of such firms: B&S and JW, Sermatec, Uni-Systems, Caldema and DLG Automação. In Piracicaba CSJ Metalúrgica was founded by former employees, by taking over the operations from the previous owners when it went bankrupt.

Market arrangements are also important as information carriers and as a source for resource allocation, through price signals indicating which sectors are profitable to invest in and also to remove funding from non-viable projects. Markets are important as processes of discovery and discarding of ideas. As Cuba does not have a market-based price-signal system it is not local market-based demand signals that have influenced local innovations and knowledge development. In Cuba, market arrangements have entered as a source of demand signals, but from foreign relations. There is no resource allocation due to price signals in the formal sector, but these processes are planned. Incentive systems for labour specialisation and knowledge development, and the weeding out of bad ideas through bankruptcy, are likewise controlled by state arrangements. At the same time, individual incentives matter also in Cuba. In activities where individual responsibility

and rewards connected to market-based arrangements have been present there has been higher productivity (Fernandez Dominguez, 2006). Individual farmers have been able to achieve yields of 100 ton cane/ha, double the average of the best periods in Cuba, and higher than the average in São Paulo (Alonso-Pippo et al., 2008). Similarly in periods when it has been permitted to establish small firms there has been better economic growth (Brundenius, 2002). Furthermore the absence of bankruptcies hamper the development of new practices, as winning concepts do not expand and poor organisations do not go out of business. The pressures on productive units are not high to innovate or to improve productivity.

The dual currency system and the system of setting sugarcane prices in local currencies but selling supplies in convertible currencies create an incentive for farmers to divert efforts to other activities, and in particular to such activities as can generate convertible currencies and many actors have instead begun to act in informal markets. Even though Cuba is a strong state with much influence in all sectors, it cannot control informal markets, and at the same time it is influential enough that it is hard to create and expand firms with long-term perspectives, as there is always a risk that the state will close down the business.

When comparing with other planned economies, one can hypothesise that such economies work better in initial phases, when revolutionary sentiments can compensate for lack of personal incentives. The economy can also grow due to forced savings that accumulate capital, but also through possibilities to mobilise the labour force. When a few industries are targeted, information and allocation problems become less problematic (Hayek, 1945). After a while, however, there will be problems of incentives and resource allocation, and in the generation of innovations.

In Cuba initiatives for innovation are top-down driven; it is the central government that decides when advances are to be tried and in what sectors. The upgrading and innovation in Cuba comes from the top down and there is relatively little space for bottom-up experimenting, which reduces the possibilities for innovation in the development of offerings and in the organisation of production. Davis (2007) quotes Pedro Monreal, who suggests that Cuba needs a thorough reform, making it more similar to China and Vietnam, as he sees Cuba as being deficient in “*calculation, motivation and innovation*”. There is a lack of markets determining prices,

reducing incentives to make an effort and take risks. As he sees it, this would require Cuba to decentralise and allow for many more areas with private markets than has ever been allowed since the revolution.

With growing industries, there is pressure on infrastructure, labour supply and the environment, which can cause problems if not properly regulated. There are limitations in infrastructure, particularly in São Paulo, and also limitations on skilled labour, especially for skilled labour for sugarcane harvesting and the metal-mechanical industry (Sartori, 2008; Santos, 2008). There have also been problems with air pollution due to burning of sugarcane fields, and pollution of water due to the leaching of industrial residuals into water; some of this is currently being addressed through legislation. These negative externalities that can be enhanced by market arrangements are not easily solved by the market arrangements, as they are outside of the direct transactions.

There have also been voices raised that relying solely on markets can lead to under-investment in basic research, thus constraining long-term innovation due to a lack of profound knowledge from which new technology is generated, as actors are given more incentives to address short-term and pressing challenges. In São Paulo there are currently worries for this. Researchers argue that universities, research institutes, and agencies are more important than ever; of particular importance is the development of new sugarcane varieties, for which it took ten years to get the first results, and now there is a need for varieties to be used with mechanised harvesting (Inovação Unicamp, 2006a). Other voices claim that funding is focusing too much on incremental engineering projects, rather than more radical and scientifically based projects (Simões, 2007a).

5.3 Local Networks Driving Innovation or Rent Seeking?

Local network arrangements have been important for innovation in the clusters and are conducive in a number of ways, by enabling joint action, diffusion of knowledge and enabling the creation of specialised knowledge and services. Local network arrangements have been very important for innovation in the clusters, and the observations in the empirical data indicate that they are particularly important in São Paulo, to a lesser degree

in North East, and with little influence at all in Cuba. The indications from respondents were that local network arrangements were most influential in São Paulo and that firms there engaged in practices of interacting with new technology providers to a higher degree than in the North East (T. Andrade, 2008; A. Andrade, 2007). This can also be due to the larger density and diversification in the local setting, i.e. there is more to gain from the actors in the local exchange; there were also responses from the North East that firms were interacting, but mainly with suppliers from the Centre South (Neto, 2007; Almeida, 2007).

Network arrangements can influence innovation in different ways, by facilitating knowledge spill-over (from formal and informal exchanges), specialisation (by setting up networks for knowledge development and diffusion), and user-producer learning (by allowing for joint development of products and processes, but also for testing of prototypes in real contexts).

First of all, there are also diverging messages coming out of the Pintec survey data (IBGE, 2002, 2010) and from the respondents, concerning collaboration and innovation. Apart from different perceptions, this could be the outcome of different interpretations of what collaboration implies. In the Pintec Survey (IBGE, 2002, 2010) the number of firms collaborating for innovation is relatively low, indicating that networks are less important, and respondents in Piracicaba said that there had previously been less direct collaboration and that they appreciated the role of APLA in creating trust among actors. At the same time, the respondents in São Paulo emphasised the role of networks for addressing joint problems, but also in the development of innovations. However, it may be that direct collaboration is not the most important form of collaboration, but that networks may still be important as sources of innovation. The firms in the Pintec survey state that external sources are highly important as sources for innovation, even though there may not be direct collaboration. Some of the most common activities for innovation have been purchasing equipment and software. With regard to purchasing new refinery equipment, there is always a need to adapt technology in implementing it, some of which can be carried out in pure market transactions. However, these processes are facilitated by more long-term network relations as there is a need to adapt technology to existing processes. An important factor to take into consideration regarding the view of networks and collaboration is that the respondents that I have interacted with are the ones that are more extrovert and are participating in different

networks; they may therefore be biasing my perception of a more pro-network view. At the same time, the presence of the many network arrangements in São Paulo, and also Falk et al.'s study (2009) on strategic alliances, implies that there are many networks in place in the Centre South; even though they are not always there for a specific innovation project, they can facilitate innovation processes.

In Piracicaba the respondents stated that different alliances, informal and formal networks have been very important, such as informal networks between industry in the form of firms like Dedini, Cosan and Caterpillar; the local municipality; universities and other research institutes, e.g. CTC (Velho and Velho, 2006; Amaral, 2006; Santos, 2006; T. Andrade, 2008). Networks in Piracicaba have been indicated as influential for the initiation of Pró-Álcool (T. Andrade, 2008), and might have been influential for Planalsucar, which was headquartered in Piracicaba (Tosi et al., 2008). There were also a number of informal networks behind the creation of APLA, both among suppliers to Dedini (Ribeiro, 2006), and among local stakeholders in the wider sugar industry (Santos, 2006; Amaral, 2006; T. Andrade, 2008). In the North East it was likewise reported that there were informal networks among millers for knowledge exchange of best practices and business opportunities (Neto, 2007) and formal and informal exchange in trade associations (Cortez, 2007; Evangelista, 2007; Moraes de Andrade, 2007). It was claimed that the informal exchange has been reduced since 1990 as competition has become tougher (Neto, 2007). At the same time, in Piracicaba it was indicated that, due to APLA and the beneficial market demand for sugar and ethanol there was an increased openness and willingness to collaborate (Santos, 2006; Castelar, 2008; Sartori, 2008). There are also formal and informal networks between university and research institutes and sugar mills (Simões Neto; Almeida, 2007). In both regions it is also the case, as a scan of the patent database shows, that there are often representatives from both industry and universities, and many persons with double affiliations; for example, the patent application from the Bioenzima firm from Pernambuco, includes inventors from Bioenzima, but also from the Federal and the Catholic University of Pernambuco, as well as researchers from the University of Caxias do Sul.

Networks are important for knowledge diffusion, as direct enablers of transmission of knowledge between actors that are familiar with each other. Networks are very beneficial for managing uncertainty, as actors have little

knowledge and an unclear view of the future, and their knowledge of present circumstances is limited and restricted to existing practices and circumstances. Working in networks in clusters provides an advantage here, as it is closer to actors with shared interests, who know the industry and with whom there are established relations. There is an advantage from creating networks to meet needs, and also networks for gathering knowledge as intelligence on a continuous basis. Since no actor by himself can gather and sort all relevant information, it is better that this is done in networks where there is gathering, validating and diffusion of knowledge.

Networks can also be supportive in managing uncertainties involved in innovation processes, such as uncertainty about goals, milestones and which capabilities to involve. There is plenty of evidence of how networks are supportive of innovation through joint action in the cases, such as the network behind the biomass gasification project, consisting of CTC, Dedini, Unica, the private companies Braskem and Oxiten, and the public research institutes IPT and IPEN (De Carvalho Varrichio and Queiroz, 2010).

Networks can also be innovations in addressing common challenges for cluster actors. Network processes of identifying and addressing common challenges can be seen as social innovations (OECD, 2005) or system innovations (Elzen et al., 2004). In these processes, cluster-based networks can be optimal, by finding a mix of actors with relevant knowledge of the industry and an understanding of what needs to be addressed and how, as in APLA. This knowledge can be combined with resources from more resourceful actors and with the means to alter institutions and find financing, such as dominant firms or public actors. Individual companies can independently influence cluster development to different degrees, but the importance of externalities and public goods means that informal and formal networks and other collective bodies are necessary and appropriate. Broad-based networks can have a greater impact than individual organisations, due to more attention, resources and influence.

There are also examples of more specific and institutionalised means of long-term knowledge development in the form of CTC, both as a closed network arrangement within Copersucar and as an open research centre (T. Andrade, 2008). In addition there is Uniduto to address logistics and transportation in the Centre South, and the Sindaçúcars in the North East are managing export terminals. Other examples are the trade associations which create and

diffuse knowledge among members, such as ORPLANA, UNICA, Sindaúcar and the sugarcane growers' association of Pernambuco, and which manage the Consecana price negotiation process. These organisations and other network arrangements have also been facilitative in education and vocational training to upgrade labour skills, such as SESI, SENAI.

Network arrangements can encourage spill-over, through support to start-ups. There are network organisations providing services to firms starting up, such as the industry organisation CIESP. In addition the presence of a network of suppliers can also support spin-offs. If an actor knows more about where necessary complementary capabilities for setting up a firm can be located, such as access to venture capital and where first customers can be generated, the start-up processes and risks of starting are much lower. It seems that in São Paulo since 1990 the complementary resources are more prevalent and also that more firms have been started with greater variety of offerings (Vian et al., 2005; da Graça, 2006; IBGE, 2010).

Local user-producer interactions through network-based relations have been very important, especially in São Paulo. The common process for development of metal-mechanical innovations in the sugar industry has been through network-based long-term interaction between sugar and ethanol producers and machine manufacturers, where the millers provide manufacturers with physical space to test their new technologies and provide feedback on technology, whereas manufacturers provide the financing and the research team (Ueki, 2007). Supplier firms like Dedini, even though they work on a national scale, benefit from the closeness in interaction, and as there is an institutional thickness around Piracicaba it is easy to match up with complementary capabilities, from different segments of the industry and research capabilities.

The respondents did not acknowledge that relations in cluster transactions were based on community arrangements (Almeida, 2007; Cortez, 2007 Neto, 2007; Amaral, 2006; T. Andrade, 2008; Vian 2006), but claimed that they are based on repeated professional transactions. Relations are built on bridging social capital that supplies trust from repeated interaction, rather than from common cultural group belonging, so-called bonding social capital (Coleman, 1988; Putnam et al., 1993). With Falk et al.'s (2009) study in mind about the number of firms seeking strategic alliances – whether this is with Brazilian partners (approximately 77.8%), or with

foreign ones – Brazilian firms seem to find it easier to work with local actors. In the Pintec survey (2010) none of the ethanol firms innovating stated that they co-operated with foreign firms, and as sources of innovation 2 out of 94 innovating firms mentioned international trade shows, conferences and information networks, suggesting that local relations are more important than foreign ones. Some of the respondents stated that it was easier to work with local actors (Neto, 2010), which may imply that shared local practices are important. Still, the respondents make no difference between Brazilian firms from the Centre South and the North East.

In Cuba the local network relations are of little importance for knowledge and innovation development in the formal sector. Key arrangements for knowledge development and diffusion, such as the research institutes, are national state arrangements. The role of personal informal networks is most likely important, but I have not received any indications of their role for the sugar cluster. Formal exchange between local actors is more of a top-down and quasi hierarchy character. There is some informal local exchange, as example personnel from the mill in Hector Molina work as teachers at the local municipal university (Caballero, 2008). In the Cuban institutional framework, it is not officially sanctioned to initiate independent networks that are outside of the formal relations. There are clear restrictions in how networks can be formed and who can be involved in processes. The arrangements are more like state conglomerates, with internal units. There are informal local networks, though, and Sociolismo is flourishing. This is a Cuban joke about how you need friends (*socios*) to survive and how friends support each other, while punning on socialism which is supposed to take care of everyone. These networks involve the disappearance of state goods that are sold on black markets, sales of illegally imported material, operation of cable TV networks etc., with links to very resourceful actors. Sociolismo is currently not a force that develops the sugar industry, but is likely one force in the emerging Cuban economic landscape.

Sociolismo relates to one of the dangers of local network arrangements that they can focus on rent-seeking activities that prevent innovation. Clusters are concentrations of actors that often have common interests in a number of issues. These interests can be addressed by local network arrangements and geared to realising mutual interests. This can be positive for society, by creating new innovations, and also negative, by preventing the development of new technologies. By rigging markets, cartel members will prevent

newcomers from entering markets and secure incomes for themselves. A secure market will also reduce the incentives to innovate and create improved products for the cartel members, as the existing business model is secured (Maloney, 2001). Cartels can destroy the long-term dynamics of a cluster. Incumbent actors prevent newcomers by putting pressures on partners in distribution chains or suppliers not to interact with newcomers, and this prevents potential competitors from accessing key resources or from selling their offerings. Vested interests can also influence and acquire special status with government, and through varying measures protect their position. The arguments are often based on special concerns, such as economic importance for distressed regions, an industry of particular interest for the nation, and of vital future potential. Institutionally oriented economic historians have emphasised how important it is for societies to have institutional frameworks that provide incentives for innovation and productivity raising, rather than rent seeking for economic growth (North and Weingast, 1989; Rosenberg and Birdzell, 1986).

In our cases there are examples of industry seeking various protective measures and practices that prevent newcomers. In Brazil there have been problems of vested interests obstructing newcomers. This has been reduced since the 1990s, but industry actors still exert strong influence over policy (Armijo and Kearney, 2008). There is still corruption and there are measures in place in the North East to protect established actors. In Cuba it is not cartels that prevent innovation, but rather the strong state and with its political centrality, with vested ideological interest that block changes that could improve possibilities for innovation in the sugar sector.

In Brazil, before the changes in the 1990s, vested interests of the sugar industry over the state arrangements have been influential, with preferential treatment, public procurement of ethanol for mixing with petrol, protective measures with subsidies, quotas and publicly regulated price levels (Gomez, 2007). One of the respondents also said that the formation of the IAA was an outcome of industry lobbying (Evangelista, 2007). The state supported incumbent interests, and made it harder for new actors to establish themselves, as there were no free rights to establish, but permission was needed from the IAA (Signorini et al., 2010). The sugar industry was also supported at the expense of other actors and technologies (Armijo and Kearney, 2008; Signorini et al., 2010). There was little competition, and

state arrangements participated in reducing these pressures (Martines-Filho et al., 2006; Roque de Oliveira, 2008).

The institutional framework and state arrangements have changed since the 1990s, leaving less scope for rent seeking, and there is increased market logic of arrangements with less direct state intervention (Amaral, 2006; Santos, 2008). Since the mid 1990s there are two new market-oriented institutions, CIMA and ANP, that have the roles of monitoring and evaluating the deregulation process and providing recommendations for the level of ethanol to be mixed into petrol (Signorini et al., 2010). Even though the role has changed, there is still major support from the government to the sugar industry, such as the mandatory mix of ethanol in petrol, subsidies to consumers for the purchase of flex-fuel cars, programmes making it mandatory for the government to purchase flex-fuel cars and subsidies to mechanisation (Armijo and Kearney, 2008). In periods of crisis the government has raised the level of ethanol mixed in petrol to 32%. These institutions are therefore important targets for lobbying (Storel, 2006).

Before the reforms of the 1990s and still to some degree, actors in the North East in the sugar industry are arguing as victims that need government support to survive, and the sugar industry is of such local importance that if it shrunk radically it would be problematic for the regional economy to handle. The sugar industry has received protection through subsidies and quotas, some of which remain in the North East. The federal government has awarded the North East the Brazilian sugar quota to the US (Bolling and Suarez, 2001; Evangelista, 2007). The quota is not a major share of the total export, but beneficial for the region, which exports 70% of its production (UNICA, 2010). Growers in the North East also receive a subsidy of BRL 5.00 per metric ton of sugarcane up to 10,000 metric tons per grower for sugarcane produced during the 2009/2010 crop, in order to balance the difference in cost of production between the Centre South and the North East (Martines-Filho, 2006; USDA, 2010). It is highly likely that these protective measures have reduced incentives for industry to upgrade and innovate, and made actors and networks in the North East more rent seeking. Also in the communication from actors, there is still a higher tendency among stakeholders in the North East to seek protection, which was also stated frankly by one of the respondents (Moraes e Silva, 2007), the representative of Sindaçúcar Pernambuco, saying that it is part of their work (Evangelista, 2007), while others did not vent strong opinions for or against,

whereas the respondents from the Centre South expressed strong feelings against regulation (Cordeiro, 2006; T. Andrade, 2008; Roque de Oliveira, 2008; Cosan, 2010)

In the 1990s many firms in the North East went out of business. However, the indications from the millers were that they viewed competition as something beneficial and that it was important to innovate (Almeida, 2007; Cortez, 2007; Evangelista, 2007; Neto, 2007). At the same time, there seems to be an interest in acquiring advantages from regulation, and the answer from Grupo JB to the question what they see as the difference between the present situation and the time before the reforms of the 1990s was: *“I think that today we are more open to innovations, the country opened the door for international players. The local relations today are very important; we have to be together to compete with the big players located at São Paulo. We have a strong syndicate that defends our interests”* (Neto, 2010).

Some argue that the sugar industry gets more attention than it deserves compared to more important industries, such as soybeans in agriculture, or the automotive and mining industries (Zylberstajn, 2006). This is also a problem related to cluster policy. Cluster policy has been argued as a remedy against problems related to directed industry policy, aiming at picking winners that contribute to rent seeking and corrupted vested interests (Nauwelaers and Wintjes, 2002; Mattsson, 2007; Europe Innova / PRO INNO Europe, 2007). Cluster policy would address industries horizontally instead of particular actors. Now, however, there are challenges with picking industry winners instead of targeting individual firms, and there is a danger that resources will be diverted to incumbent industries at the expense of emerging ones that do not have the same established resources to voice their interests that might actually be in greater need of establishing markets.

In Cuba the major vested interest preventing technology development is not from rent-seeking local networks, but the political establishment. There is an ambiguity from top levels about the sugar industry and also a conflict of interest between needs of immediate change to revitalise the sugar sector and the overriding political goals, or foreign policy goals. Here we have the examples of problems of dual currency system and price system that affects sugarcane growers negatively, and problems of not allowing for bankruptcy, for new firm start-up or for the growth of successful firms to spur innovation. There is also ambiguity in the central government about the

view of the sector and whether it should be further developed. For the political side it symbolises a negative past which it is desirable to move away from (Mesa-Lago, 2005). At the same time there is a lot of interest from different actors, within ministries, the industry and at universities (Nova Gonzalez, 2006, 2008; Alvarez Delgado and A. Torres, 2007) and foreign interest to revive the industry (Rodriguez, 2007).

There are also connections to foreign policy and the interest among Cuba's political establishment to act as a moral power in international forums. When ethanol as an automotive fuel first became an international topic, there was an official Cuban interest in it, and there were discussions with Venezuela for joint development. However, after an alliance between the US and Brazil to stimulate ethanol as an international commodity and to build global markets, highly negative messages were communicated by official sources (Carroll, 2007). This also coincided with a strong international current against ethanol as automotive fuel of a fear of conflict with food production and Havana was filled with official billboards proclaiming the message that it is only the mad First World that drives their cars with food.

Networks are important for collaborative action, managing uncertainties and enabling innovation processes, but there is also a danger that these turn into cartels that prevent innovation.

5.4 Quasi Hierarchies – Development and Diffusion of Knowledge

Quasi hierarchy relations have been influential through the generation and diffusion of knowledge. The dominant firms in quasi hierarchy relations are also important as change agents, as they have the resources and influence to make other actors in the cluster change their behaviour.

The dominant firms are often also the larger firms in the cluster. In the case of Brazil, large firms are very important for innovation through the relative amount of innovation, their value and types, according to the Pintec survey (IBGE, 2010). One can see that in 2008, of the large Brazilian firms (500 + employees) 72% were innovating and stood for 68% of the value of all innovations, whereas small firms (10–29 employees) stood for 4% of the value, and 37% of the small firms were innovating (IBGE, 2010). Of the

innovations that the different types of firms generate, large firms are more prone to generate innovations that are new to the market than small firms. Of large firms in industry (not services) 26.9% create product innovations new to the market and 18.1% process innovations new to market. For small firms the figures are 4.1% and 2.3%. Furthermore, large firms seem to develop more proprietary knowledge as part of innovation; in the Pintec 2008 survey, the main activities for innovation among small firms were buying equipment 62.9% and training of personnel 40.9%, whereas for large firms the figures were buying equipment 62.6% and training 54.5%, but also carrying out industrial projects 40.3% and internal R&D 39.1%.

Quasi hierarchy arrangements develop more proprietary knowledge, which is also diffused to other local agents, through informal networks, firms' spin-offs and formal relationships, such as with suppliers.

In Piracicaba there are a number of notable sugar mills, such as Copersucar, Cosan and LDC-SEV, which have been beneficial for the development of process equipment for Dedini, which has learned to develop competitive technology by providing it to the market leaders and by the ability to develop the products in the facilities of the running mills. Dedini has also had its own mills in one arm of the company. The millers are also diffusing knowledge about sugarcane growing and harvesting practices to sugarcane suppliers (Zylberstajn, 2006), as reflected in the way that Cosan makes it mandatory for sugarcane suppliers to operate according to their prescriptions (Cosan, 2010). This is not always desired and the knowledge spill-over can be of a forced character. In Cuba there are formal structures for knowledge sharing between the different organisations in the region, where the sugar mill dominates the surrounding units, so it can be seen as a quasi hierarchy arrangement that diffuses knowledge (Martinez, 2008; Leon Gimenez, 2008). Of increasing importance in Cuba is the presence of foreign firms, and joint ventures that implement new knowledge, which is later diffused to other parts in Cuba, for example by labour rotation (Dominguez, 2004).

Quasi hierarchies are also important for user-producer learning. Dedini serves as a source for user-producer learning for smaller local metal-mechanical industries and larger but less well established firms like CSJ Metalúrgica (Sartori, 2008), by defining requirements and specifying requirements for delivery to them (Freies, 2006).

Quasi hierarchies can also be a form for complementarities, between dominant forms that can obtain niche products from smaller firms to offer or hire suppliers for certain processes not deemed necessary to have in-house, and smaller firms can gain market access and access to needed resources. For example, there is order sharing between Dedini and CSJ Metalúrgica (Sartori, 2008), which can offer some variety in industrial capabilities that can complement each other's offers; likewise SMAR Equipments are supporting DLG Automação Industrial. In Cuba there has been a process in which large state farms have been broken down into independent units. However, these units are still co-ordinated by the central mills that influence their activities. Considered quantitatively, large Brazilian firms are also more prone to collaborating and using a wider array of sources for innovation than smaller ones and they carry out a broader range of activities than smaller firms. In 2008, 10.1% of small firms in industry were collaborating for innovation, whereas 35.3% of large firms were collaborating for innovation. There is not such a great difference as regards who it is important to collaborate with; most important are suppliers and customers. The one notable difference is that for large firms, universities are noted as relatively important actors for collaboration, whereas in the order of relevance for small firms consultants are more important. The most important sources of innovation are for large firms customers 50%, then come non-R&D internal sources 45% and internal R&D 40.6%, followed by suppliers 45.5%. For small firms the most important sources are information networks 49%, customers 44%, internal non-R&D 34.6% and suppliers 36.2%.

Quasi hierarchies can also stimulate specialisation and division of labour. Sugar refineries can produce their own cane, but it is very common to purchase cane externally as well. Respondents say that it is a risk management strategy to purchase cane externally, so that not too much or too little cane is produced (Neto, 2007). There is also to an increasing degree a process of more professional relations between employees and employers, with an increasing number of services being purchased from external resources, such as construction, transportation (Dubeaux, 2007; SEBRAE, 2007), but also consultant services such as the ones offered by Cana Vialis for optimising cane types with land. In the metal-mechanical industry there is also division of labour, and Dedini has sold off some units such as the division that produced sugar and ethanol to focus on its units

that develop processing equipment (Inovação Unicamp, 2010). In Cuba there is a process of both decentralisation and centralisation, with more units being independent but still co-ordinated by the central refineries.

Large firms are also important for diffusion of market knowledge requirements and as channels to international markets, where small firms can piggyback on dominant ones to reach markets. In the case of Piracicaba, large firms like Dedini, Sermatec, Mausá, CSJ and NG are important for small firms to reach national and global markets (Calil, 2008).

The dominant firms are also important as enablers of joint action activities, as these are the ones with resources, influence and also holders of strategic knowledge. They can dedicate their own resources, and also influence other smaller actors to participate in projects in order to keep good relations with dominant actors. From the responses in the interviews about APLA and observations of actors behind network projects like Uniduto, it appears that the large firms are very influential in forming the initiatives.

There are dangers related to the powers of the dominant firms. They are in positions where they can acquire benefits from the government at the expense of emerging firms and technologies. There are indications that this was the case in Brazil before the 1990s, but that later the problem of vested interests has decreased somewhat (Armijo and Kearney, 2008). They can also pressure other firms into non-optimal activities, such as locking them in to certain behaviour that can prevent innovation and upgrading. In São Paulo there is a richer weave of different actors and industries. There is more division of labour and more different specialised actors. Therefore, even though there are large firms, they do not become as dominant, and smaller firms run less risk of being locked into one actor's processes.

5.5 State Arrangements – Building Capabilities, Addressing Collective Problems and Fostering Bubbles

In all the cases there have been state arrangements that have enabled specialisation, encouraged knowledge spill-over and addressed joint problems. State arrangements have stimulated innovation and growth of clusters by provision of funding for innovation projects; procurement of

ethanol; provision of specialised services and protection of industries through quotas, tariffs and subsidies.

Investments in science and technology have fostered innovations, which has raised productivity and competitiveness. In all the cases state arrangements have played an important role in building up capabilities. In Brazil the state, through the Planalsucar and Pró-Álcool programme, has created industrial capacity and know-how about using ethanol as an automotive fuel. In general in Brazilian R&D funding, the state is the major investor (Brito Cruz and de Mello, 2006), but in the sugar industry it is the private sector (IADB, 2007; Amaral, 2008). Nevertheless, compared to average investment levels in R&D in OECD countries, 2.2%, the Brazilian average is much lower, 1% (Brito Cruz and de Mello, 2006). In São Paulo it is not only the federal government that is an important actor, but also the state of São Paulo; two thirds of the funding of R&D in the state is public, and it is Latin America's second largest investor, ahead of Mexico and Argentina (Brito Cruz and de Mello, 2006).

There have been education programmes and creation of research capabilities. Cuba has a population with a high degree of education (Brundenius, 2009) and São Paulo also has a high level of capabilities, but still with many people with lower skills (Santos, 2008) and potentially a need for even more skilled labour (Brito Cruz and de Mello, 2006). Currently there is an expansion of private higher education facilities, but these are of lower quality than public universities and are also focusing more on low-cost courses such as management and social sciences (Brito Cruz and de Mello, 2006). The North East has some capabilities, but less than the other two cases. There has been build-up of skills, both as a long-term investment, and also as schemes to face challenges of unemployment and needs for reskilling, like the Cuban programme of universalisation of education. In São Paulo a number of programmes and schools have been initiated to give training in the large variety of labour competences needed in the growing sugar industry (Santos, 2008).

State arrangements have facilitated change in a number of industries related to ethanol and have created a system innovation that has been of major importance for the sugar clusters of Brazil, in the form of the system for ethanol as automotive fuel that did not exist elsewhere before. The state in Cuba has furthered the capabilities in the sugar sector, through investments

in machinery and in new knowledge from research institutes, such as new cane varieties and local harvester technology (Zimbalist and Brundenius, (1989). Through social security programmes and reskilling it has overcome vested interests that prevented the upgrading of the industry (Edquist, 1985)

State intervention is often justified by arguments of the character of market failures; one such example is the argument in this thesis that there is a need for government financing of basic science, otherwise there may be underinvestment that in the long term will reduce innovativeness. In Brazil, private investment in R&D is 0.4% of the GDP, which is four times lower than the OECD average, and state arrangements are very important for scientific research (Brito Cruz and de Mello, 2006). In the sugar and ethanol sector private investments are dominating though (IADB, 2007). With regard to the development of Brazil, it is frequently argued that there is a need for more and better skilled labour and also better connection between university and firms in formulating research agendas (Meyer-Stamer, 1995). It is likely that the sugar sector is one of the areas in Brazil that is performing best with regard to connections between university and industry, despite Pintec indications of low collaboration rates (IBGE, 2010). It is also the sector where private efforts have been most influential (Tosi et al., 2008). In general the previous Brazilian policies of import substitution lead to local firms importing foreign technologies, and adapting it to local markets, with little interaction with universities. However, in the case of ethanol as automotive fuel, genuinely new technology was developed and there was more interaction with academia (Meyer-Stamer, 1995).

However, not only markets can fail, but all types of governance mechanisms including government action (Jessop, 1998). There is also discussion of systemic failures connected to innovation system analysis, i.e. an innovation system is underperforming in the provision of certain key factors for innovation (Chaminade and Edquist, 2007), or different mechanisms counteract each other, creating problems that reduce possibilities for innovation (Andersson et al., 2004). In all the cases there have been a number of state interventions that have enabled innovation, such as the Pró-Álcool and Planalsucar programmes, and other measures that have fostered problems that constrain innovation, such as protective measures that have reduced the need for innovation (Meyer-Stamer, 1995).

It is commonly argued that government should counteract market herd behaviour that creates bubbles. However, in the cases of Cuba and North East Brazil it can be seen that state arrangements have fostered bubbles and stimulated the flow of resources to regions and sectors that would not be competitive at the stimulated levels by themselves, and when these policies were removed the needs for restructuring processes have been tougher, due to more dramatic changes taking place at the same time.

In the case of North East Brazil the price regulation and quotas that existed before 1990, and the current subsidies and export quota rights, were and are measures to protect the industry, rather than to foster innovation. The natural conditions in the North East are less favourable than in other parts of the country and production costs in the North East are non-competitive for many actors, although with exceptions (Morais de Andrade, 2007; Almeida, 2007). The regional economy itself is less developed, with few other alternatives of employment, and work in the sugar industry provides relatively favourable incomes for non-skilled labour (de Santana, 2007). The protection of the North East has existed for a long time, due to lagging economic development. These protective measures have had the result that sugarcane farms and mills remained or expanded in areas of hilly terrains that cannot produce sugarcane at competitive prices (Dubeaux, 2007). However, the protection was not used to upgrade firms, but sustained non-competitive practices among firms, as these did not have to innovate and implement new technology (Meyer-Stamer, 1995). In the North East few local technologies have been developed for the specific local conditions, whether for machinery or sugarcane varieties (Simões Neto, 2007).

After deregulation, many firms could not meet the competitive pressures from the other parts of Brazil and went out of business. There are still a number of firms in place that would not survive full competition, in particular among independent sugar cane farmers (T. Andrade, 2008). After the 1990s the sugar cluster shrank substantially and many mills were closed down, particularly in Pernambuco, and a great many people lost their job at the same time. There is a potential danger that even further more mills will be closed down if protection disappears, and it is almost certain that the number of people employed in the cluster will decrease as firms begin to mechanise (Almeida, 2007).

Likewise, the development in Cuba has blown up a sector beyond competitive proportions. It has been argued that one of Cuba's greatest challenges is that it has created a culture of producing sugar regardless of costs (Alonso-Pippo et al., 2008). This culture was built up by a number of factors, such as the political campaigns to reach short-term goals that at the same time destroyed long-term objectives, e.g. the campaign of 1970 to produce 10 million tons of sugar. Also, there have been arguments in the political rhetoric that are negative about paying undue attention to numbers instead of a revolutionary spirit (Alvarez, 2005). This culture was also strengthened by the trade agreements with the Soviet Union that offered subsidised prices for agricultural inputs, and agreed to pay substantially higher prices for Cuban sugar than world market prices, as well as long term credits at low interests (Brundenius, 2002). For example, in 1989 the COMECON price was three times the levels in the international markets. In these years earnings from sugar represented 75% of all Cuba's export earnings (Pollitt, 2004). They could also buy fertilisers and metal-mechanical components and machinery at subsidised prices, which allowed for high degrees of mechanisation and use of fertilisers (Fernandez Dominguez, 2006).

During the 1970s and up to the 1980s the sugar industry expanded and the growth model was mainly of an extensive kind, with increased land use, but also with increases in sugarcane yields. Cuba earned a high profit despite heavy use of imported inputs, low labour productivity and organisational inefficiencies (Pollitt, 2004). At the same time there was innovation and upgrading of the industry, such as a development of the capacity for science and technology, a metal-mechanical industry, mechanisation of harvesting, and a number of new cane varieties were developed and a great number of derivatives (Zimbalist and Brundenius, 1989). In this upgrading process, however, despite the knowledge build-up and the mechanical and industrial capacity to build more advanced boilers, and strong financial support, few new mills were built (only eight) and there was little renovation of existing ones (Alonso-Pippo et al., 2008). The knowledge of how to produce the derivatives from the sugar industry was hardly utilised and has had little economic importance for the Cuban economy (Monreal, 2004); for example, only eight mills were upgraded with capacity to produce electricity for the grid, and there has hardly been any production of ethanol for fuel at all (Alonso-Pippo et al., 2008).

Later, when the favourable deal with the Eastern European countries disappeared, the Cuban sugar sector encountered grave problems. There have been a number of rounds of attempts to revitalise it, with downsizing, reducing the number of active mills and land use for growing sugarcane, upgrading equipment, and also restructuring the organisation through the conversion of state farms into co-operatives. All in all, it seems as if the sector keeps on shrinking despite these efforts. The reason is a combination of factors. First of all, the supply-side driven expansion of the sugar cluster and institutions has created an apparatus that is greater than current needs and availability of sugarcane to process. The expansion was carried out with no connection to the needs and costs of carrying out activities relative to potential incomes and ability to pay for the practices in the long run. It expanded into some non-productive lands that will not be used in the future (Sao Pensa, 2007), but there are also problems related to inefficient organisation and incentive problems. As there is no market that sets prices, there is no feedback channel through price mechanisms to industry, but as there are also restrictions on freedom of speech, other channels that communicate needs for innovation or alteration of practices are also limited.

In a similar fashion, one can see that the protective measures in the North East of Brazil are disturbing feedback signals from the price mechanism that distort allocation of resources and input to innovation processes, both as incentives for creating and applying innovations, and also for sorting out bad practices and distribution of resources to more beneficial practices.

Cuba has carried out programmes restructure the industry, and more changes are on the way. There have, however, been system-level conflicts between different needs and ideological views that have previously blocked some changes from taking place, as overriding goals of the revolution and the ideology have had higher priority, rather than permitting firm start-ups or altering the system to allow for price/market mechanisms or foreign investment.

At the same time, measures and activities have been implemented to manage restructuring in orderly ways, and not just abandon the unemployed. One important measure has been the process of universalisation of education, with local universities opened all over Cuba which have begun to enrol students, many of whom are former sugar industry employees (Monreal et al., 2005). In the North East there will be a need for reskilling of labour, if

the industry mechanises, as there is a shortage of skilled labour that can handle the machinery, and also of personnel to manage maintenance etc. This process will also lead to unemployment for many people (Almeida, 2007; de Santana 2007). Cuban reforms could potentially be inspiration for the North East, as could those in São Paulo, where there have been programmes for technical schools, such as ETEC and FATEC, at secondary and tertiary levels, but with professional curricula, to meet the growing demand for labour with technological skills (Santos, 2008).

There are respondents who fear that current policy support to the sugar industry in Brazil, with beneficial financing for upgrading of machinery and loans to build sugar mills, will lead to an over-establishment of industry in Brazil, as investors are over-estimating potential future benefits; in particular there are actors who have great hopes for exportation and some without prior market experience (Vian, 2006). There is a fear that the last few years have been a cyclical boom due to favourable global prices (for oil) and demand for sugar and ethanol, but that these price levels may not remain, and there will be busts in the industry, as happened in the 1970s and 1990s (Storel, 2006). However, oil prices have fallen and there is global recession, but the sugar and ethanol industry has not entered a slump. This can be due both to the strong local demand for ethanol, and also to global demand for technology and for ethanol, as countries are beginning to follow the Brazilian example of blending petrol with ethanol. However, we do not know the future or what energy matrixes will be.

The challenge with the protective measures and boosting of clusters as in North Eastern Brazil and Cuba is that the problems of restructuring become much tougher when the threshold is reached when it is not possible to keep on subsidising unproductive industries, and this also seems to decrease the incentives for the protected industries to innovate. It is likely that it is better for clusters to have measures that can manage flexibility and restructuring gradually, with a number of firms and ideas weeded out over time (at higher and lower frequency depending on business cycles). It will also be necessary to find means to educate and reskill labour continuously, instead of keeping up industry for long periods of time, and then having a much greater crisis, when everything implodes at the same time. However, most projects and firms will fail over time (Ormerod, 2005), and there is not one secure form of arrangement that can guarantee processes. This is also an argument for systems of plurality in institutional arrangements and of actors; a mix of

arrangements and actors will reduce risks of failure, as there are more processes in place working in parallel but with different approaches to find solutions (Taleb, 2007). With a limited set of organisations restricted in forms of work practices, there is less chance that solutions will be identified, and when these organisations fail, it is more costly and has a greater impact on society.

5.6 Arrangements, Externalities and Innovation Performance of the Cases

There are clusters in all of the cases, but the role of cluster externalities for innovation in the cases differs, as does the innovation performance. The case where cluster externalities are most important is São Paulo, whereas cluster externalities are less important in the North East of Brazil and in Cuba.

Cuba has generated a number of innovations and also scientific and technological knowledge of importance. However, it is to a less extent cluster externalities that drive innovation, and one important reason for this is the lack of local market and network arrangements that can channel demand signals. The most important driver of innovation in Cuba is national state programmes and international relations, which have been and are very important. It is through state arrangements that production is organised, and the creation of the research institutes and funding of universities, and it is through educational programmes and social security systems that restructuring has been facilitated. International demand is transferred to the national system through planning by state arrangements, which in the 1980s led to a massive growth due to the favourable conditions from the Eastern European socialist countries, and also in the 1990s there continued to be efforts to keep up levels of exportation even though production was inefficient, as it was an important source for foreign exchange. The role of Cuba's sugar industry for export earnings is still important and is estimated at around 5–10%, but used to be 75% at its highest peak, whereas the value of the production of the sugar industry is only around 4% of the GDP (ONE, 2008b). At the same time, when international prices have begun to become favourable, the local price system has not turned the international signals into more beneficial local signals that would raise incentives for local farmers to produce sugarcane. Likewise,

the prohibition of entrepreneurial activity in the formal sector has decreased possibilities for innovation. Cuba is keeping up its knowledge-based capabilities, with many researchers in a number of highly qualified institutes. Their services are exported, and at the same time the sugar industry in itself is shrinking, with less production and fewer resources utilised. There is a possible mismatch between the S&T side and the production apparatus. Even though the production at the end of the 1980s was most likely a boosted bubble, there are possibilities to raise production again; the current infrastructural capacity is for 4.5 million tons of sugar (Nova Gonzalez, 2010). There are possibilities with sugar exports and ethanol as a source for bio-energy for the domestic market.

In the North East of Brazil there has been less innovation and less new technology development than in Cuba and São Paulo. There are some differences between Alagoas and Pernambuco. Alagoas is still expanding slightly, whereas Pernambuco is contracting. In Pernambuco the refineries have been more family-oriented, with more financial problems in the 1990s, and they have also implemented new technology to a lesser extent than in Alagoas (A. Andrade, 2007). There are also poorer natural conditions than in São Paulo, but through innovations productivity has been raised. In the North East, as in Cuba, the national and international relations have been more important than the local ones. Firms have been supported in growth through quotas to exportation, through regulation of prices, from subsidies and procurement of ethanol, which are outcomes of national policies. This has also to some extent reduced the needs to innovate. Local relations and networks have been less influential for innovation. There have been some local research capabilities, but these have been set up through federal universities and programmes like Pró-Álcool and Planalsucar (later RIDESA). Local industry is participating in the financing of the Carpinas research station. The supplier industry is much thinner in the North East, with fewer firms originating in the North East, but being local offices of firms from the Centre South, like Dedini. The feedback from firms in the North East is that many of them, if they are innovating, do so more by implementing technology developed in the Centre South (Neto, 2007; Almeida, 2007; T. Andrade, 2008). Before the 1990s, little innovation activity was taking place at all, but there was a surge in ethanol production and also rising productivity levels for ethanol and sugar yields. Since the 1990s innovation has increased and there is greater use of technology, even

though the cluster in Pernambuco is shrinking and growing slightly in Alagoas. There are also examples where mills are reaching high levels of productivity and also diversifying into new product segments, such as ethanol and bio energy. There are also rising rates of innovation (IBGE, 2010) and growing numbers of scientific articles published, indicating that more local knowledge is being developed.

Cuba has a large scientific and engineering capability. In North East Brazil there are few local S&T capabilities, but as indicated by Pintec data (2010), industry does not consider universities and research institutes as important sources for innovation, preferring suppliers. This is also the case in São Paulo, but I would argue that this is possibly a misperception of expectations of how knowledge is diffused from universities. There are indications from mills both in the North East and in Cuba of collaboration with universities in specific projects; students are allowed to carry out projects with the mills, and the organisations employ people from universities who bring with them new knowledge and absorptive capacity. In addition, I would argue that the presence in São Paulo of broad bases of different types of knowledge from universities and research institutes, and also from different but related areas, has been positive for the innovations generated, through the development of new and relevant knowledge, capabilities of employees, and formal and informal networks between firms and between firms and research organisations.

The strong knowledge base and the presence of a broad variety of institutional arrangements seem to be beneficial for the strongest case, São Paulo. This is also the case where local relations matter the most, as local markets drove the development of equipment for the ethanol industry, local networks initiated the research institute CTC, local networks are addressing joint infrastructure problems, and local networks are collaborating on innovation projects, such as the Dedini rapid hydrolysis, which is led by Dedini but involves local partners from CTC and Copersucar, as well as actors from Universities and financial assistance from FAPESP. There are important informal professional networks, consisting of important actors from some of the country's leading firms and research organisations, such as Dedini, Cosan, Copersucar, CTC, ESALQ and Caterpillar, that are exchanging information, but are also behind the initiation of different projects like the APLA. There are a number of local large firms that develop new knowledge, which is also diffused to local smaller partners. Local

municipalities are also participating in projects, like the APLA, and setting up training programmes to facilitate upgrading of labour skills. There seem to be some problems of congestion, but not of any type of lock-in blocking out new technology.

São Paulo has advantages through favourable natural conditions, better transport and energy infrastructure, and the country's largest market. However, the presence of the rich mix of actors from all of the value network, of producers of ethanol, sugar, sugarcane, and harvesting and process equipment, specialised consultants, research organisations and universities, has been very important for diversification of the industry and also for raising productivity levels (Tosi et al., 2008). Also, there is a mix of different research organisations, with networks like CTC, state-funded universities like ESALQ and private companies like Caña Vialis, which generates different types of knowledge outcome, which is also diffused in different forms. Local relations matter most in São Paulo, but there is also to some degree a chicken and egg situation: there is a broad base of actors and arrangements that can be drawn upon, and at the same time this generates a market for more specialisation. In the North East, by contrast, there are fewer local capabilities, and in order to remain competitive there is a need to implement technologies from external actors. There ought, however, to be growing markets for specific technologies, such as the Implanor mechanical harvesting equipment, and leasing of such equipment or buying the service of harvesting from specialised firms, as well as specific sugarcane varieties for the North East.

In Cuba, one of the great challenges is the lack of dynamics, due to the absence of market and network arrangements. São Paulo benefits from complementarities in institutional arrangements that generate different types of knowledge and enable different kinds of processes, like development blocks (Dahmén, 1988). For technology and industries to develop, complementary industries and technologies are needed; e.g. for ethanol cars to develop there is a need for cars, fuel and infrastructure in the form of filling stations. São Paulo's richer mix in arrangements and presence of different institutions and co-location of other types of industries has generated possibilities to develop more complex innovations. Another example is the growth of the metal-mechanical industry, as a complement to the sugar industry, influenced by technological advances in other industries. These complementarities also exist in the cluster.

Cuba has been almost a monoculture of institutional arrangements. Innovations were nevertheless generated and the industry was upgraded as regards mechanisation and education of the labour force. There was an institutional thickness growing with regard to science and technology capacity, and improving productivity figures. It seems here that the state has been able to overcome different kinds of vested interests, such as trade union objections to upgrading, due to fear of job loss, and to align interests to develop the industry (Edquist, 1985). This can partly be explained by the drive to develop the industry and from available resources from the Eastern Europe allies. Also, the strong state can force protesters to comply with its will. At the same time, Cuba managed to take the knowledge input and subsidies and turn them into innovations and growth of the industry. With the present situation, however, one can question how long-term sustainable the practices have been. Since 1993, there have been recurrent problems of output and also breakdown of equipment and falling levels of productivity (Alonso Pippo et al., 2008). If the political interest together with strong foreign support drove the industry and innovation in the pre-1993 period, the lack of political interest and vested interests preventing structural changes in the post-1993 period may be the strongest challenge to the development and survival of the industry. In the post-1993 period innovations are radically decreasing, as are productivity figures. There is much idle capacity, and a great deal of old equipment needs to be replaced. There seems to be a great problem in delivering sugarcane to the industry, due to incentive problems and the lack of price signals in the system. Even though the world market price for sugar is very high, it is not translated into higher incentives for farmers in Cuba.

This is contrary to how Brazil is benefiting from the positive world market demand for sugar, ethanol and equipment for ethanol production, using this to develop the industry, which spurs development through market mechanisms, and the state is also supporting the development from the highest level. The Brazilian president Lula has seen the ethanol industry as a great opportunity to develop the country and a number of policy measures to boost the sector have been carried out, both by developing local capacity and also by influencing world markets.

In all the cases there has been institutional change. From the outcomes it seems that in São Paulo there has always been a greater acceptance of market arrangements, and the shift in the 1990s was less costly for this region. It has

rather stimulated a greater growth of the industry, with more innovation in the form of new firms, product processes, business models and ways of organising the industry, such as mechanisms that have replaced state co-ordination of actors' interest like the Consecana price system and UNICA. In the North East and Cuba the shift came more due to external shocks, and these clusters had been boosted beyond sustainable levels, and dealing with structural adjustments has been more painful than in São Paulo. It is possible that there are currently more negative cluster externalities than positive ones, such as lock-in in infrastructure and capabilities. In the North East there is also more innovation since the change, but the cluster is shrinking. There are new products, processes, business models and organisations like the ones in São Paulo, many of which are copied from the Centre South, and networks still seem less focused on innovation activities than in the Centre South. In Cuba the cluster is still in stagnation, but there are interesting possibilities, with the economic changes taking place at the moment.

6. Conclusions

6.1 Relation Arrangements, Externalities and Innovation

The objective of this thesis has been to explore the cluster concept and its role for innovation. The particular area that this thesis has addressed is the role of institutional arrangements in clusters for innovation. The approach has been to use a broad view of the cluster concept, but focusing on five different externalities that are related to innovation, and four categories of institutional arrangements that govern the transactions in clusters.

The findings are that institutional arrangements matter for whether clusters are conducive to innovation or not. Cuba is institutionally thick, with a broad set-up and critical mass of actors in related industries that are geographically concentrated, yet there is little innovation coming out of the cluster, particularly compared to São Paulo, which also has a dense cluster, but a broader range of institutional arrangements. At the same time, innovation and firm growth are a stronger factor for cluster growth than a cluster itself is a factor behind innovation and growth *per se*. Of our clusters São Paulo is innovating and growing, but the North East cluster has decreased in terms of firms and employment, and is rather flattening out firm-wise and will most likely decrease further employment-wise. Likewise, in Cuba the cluster is shrinking and innovation decreasing. Clusters differ with regard to the presence of institutional arrangements, and the mix of arrangements will have an impact on the outcome of innovation. There can be clusters with few externalities that are conducive to innovation, due to the set-up of institutional arrangements and other clusters that are less institutionally dense, but with more favourable institutional arrangements. For example, Cuba used to have better technological knowledge bases than São Paulo and still has advanced knowledge, more so than the North East. However, due to the mismatch of institutions and the current institutional arrangements there is less innovation coming out.

The institutional arrangements differ with regard to how they provide incentives, enable or constrain innovation. Cluster externalities that support innovation also provide incentives in different ways, constraining or

enabling innovation, and there is stronger connection between some arrangements and externalities, as there are better matches between the structures, such as market arrangements with intense competition and networks with joint action. It seems that the different arrangements are more connected to different externalities, and have greater influence on these.

- The strongest and most unique connection for market arrangements is to give incentives to intense competition, but this also gives incentives to specialisation and user-producer learning, and can counteract vested interests. It is not appropriate, however, for collaborative endeavours of joint action, and can constrain innovation through congestions and lock-in due to under-investment in long-term knowledge.
- The strongest connection of networks is to enable joint action and knowledge spill-over, but they are also positive for enabling user-producer learning and specialisation. They can constrain competition by forming vested interests that prevent newcomers.
- The strongest connection of quasi hierarchy arrangements is to enable user-producer learning and enabling and providing incentives for knowledge spill-over, but they can also enable specialisation and joint action. On the other hand, they can constrain innovation through vested interests and cognitive lock-in.
- The strongest connection of state arrangements is to enable joint action, specialisation and knowledge spill-over, and enabling and providing incentives for user-producer learning, and they can constrain innovation by supporting vested interests and stimulating congestion and lock-in.

Table 30 gives a summary of how institutional arrangements can affect cluster externalities that have an impact on innovation; the matrix is based on the findings from the three empirical cases.

Table 30: Summary of how institutional arrangements can affect cluster externalities that have an impact on innovation

	Intense competition	Knowledge spill-over	Specialisation	User-producer Learning	Joint action
Market	Incentives for innovation. Competition with known rivals. Congestion and Lock-in.	Enabling through labour rotation. Enabling through start-ups.	Incentives to increased specialisation and division of labour	Market signals for demand. New firms help from complementarities.	Do not enable joint action
Network	Cartels can prevent competition, influence policy.	Enable spill-over from informal and formal networks. Creator of knowledge that is spun out.	Enabling through networks that provide specialised services & carry out research. Can enable division of labour.	Professional networks enable technology development.	Organisational innovations address problems of inertia and lock-in.
Quasi hierarchy	Incumbents can prevent new comers, influence suppliers and state.	Dominant firms create new knowledge, diffused to suppliers formally, through informal networks, spin-offs.	Division of labour through outsourcing.	Dominant firms diffuse knowledge to suppliers; serve as testing grounds for suppliers, and as market channels.	Influential, due to resources and power. Complementarities of marginal and large-scale volumes of small and large firms
State	Can constrain competition or enable by preventing incumbents from blocking newcomers. Can stimulate herd behaviour.	Enable knowledge development and diffusion through creation of universities and institutes, and financing of activities in institutes. Also through support to start-ups and networks.	Enable labour specialisation through education and training. Can support firm specialisation, funding and training for innovation.	Enable user-producer learning through public procurement and interaction public service providers and private actors. Can give incentives through legislative requirements. Can improve complementarities by service provision.	Can address constraints e.g. congestion and lock-in, by investments in basic science, education, reskilling and in infrastructure. Social security systems can reduce vested interests against innovation. System-level innovation. Deliberative projects. Can block innovation through conflicting political vested interests.

Some of the suggestions from cluster theories regarding how cluster can be beneficial for innovation were not identified in the cases, such as intense competition based on personal rivalry for social standing, yet competition is not blind but the actors know who their competitors are. If there was any kind of socially motivated rivalry it was more of group rivalry between São Paulo and the North East of Brazil than between individual entrepreneurs. Similarly, it was not found that social community relations were a basis for

collaboration. Relations in the clusters were based on professional relations. There were important networks in the cases, but these were based on so-called bridging social capital that is built up by collaboration over time. Furthermore, the discussion on specialisation in the theoretical background focused more on the incentive side, from market arrangements to stimulate specialisation among labour and firms, but in the empirical material both state and network arrangements have been important for enabling innovation through different arrangements for creating and diffusing new knowledge.

In different places there can be institutional arrangements that dominate the other arrangements and will also have an effect on how the other institutional arrangements can have affect innovation, as in Cuba, and in Brazil before the 1990s. In none of the cases there has been only one type of institutional arrangement in place, even though Cuba is dominated by state arrangements. The role of markets and networks in Cuba is relatively unimportant, as the state arrangements are so dominant that these do not have any influence. Furthermore, market arrangements had less influence on cluster externalities in Brazil prior to the 1990s, as these were controlled by state intervention which in turn was influenced by informal networks of dominant market actors (Armijo and Kearney, 2008).

It is hard to connect a particular arrangement and externality to a type of innovation (such as product, process, incremental or radical). In the literature it was indicated that markets are better at incremental and process innovations as they deal with more well-defined products. In more radical innovation processes actors deal with previously unknown processes and therefore it is hard to specify all parts of a process, as network arrangements are more open to deal with issues without the same amount of prior description of which kind of activities to include, costs or timelines; they are more apt for dealing with radical and product innovation (Hollingsworth, 2000). These arguments can be supported by our data, in the North East of Brazil where there are fewer networks in place than in São Paulo; there is less innovation in general, but also less radical innovation and innovation new to the market, and fewer product innovations (IBGE, 2010). Likewise, Cuba has few networks and fewer radical innovations and more incremental ones. However, Cuba has developed more technology and upgraded the sugar cluster before 1993, and at that time there were few networks in place. At

the same time, clusters do not seem to be the main driver of innovation in Cuba.

In the analysis of innovation performance, the indications are that the Brazilian cases that have become more market-oriented over time have also altered the patenting pattern from product-oriented towards more process-oriented innovations. Which period and types of institutional arrangements have generated the most radical innovations is hard to tell from the material, but from 2000 to 2010 there has been an increase in innovations that are new to the market and the number of firms that are innovating is increasing (IBGE, 2010). There are examples of radical innovations in the 1970s and 1980s, such as the development of the system for an ethanol-based automotive system, and from the 1990s onwards it has been affected by many types of institutional arrangements. At the same time, the radical innovations did not come from the North East, but from São Paulo. With regard to the patent analysis, Cuba has produced mainly product innovations throughout the time span explored. However, an interpretation of this difference could also be that it is an outcome of the Brazilian institutional set-up having altered with more opportunities to commercialise knowledge in different forms. There is more division of labour and more specialised actors working as suppliers, and there are greater opportunities to protect and commercialise intellectual properties, by licensing and by building firms around process innovations. Whereas previously such knowledge was mainly implemented into firm processes, and traded through the production of final goods, e.g. in the case of Cosan sugar or of Dedini through the engineering skills acquired when building and trading equipment. In Cuba, where the economy is like a large conglomerate and much of the trading is carried out with international partners that take care of the good, such as sugar or vaccines, it is still more important to protect product innovations through a patent, whereas process innovations are rather implemented in processes. The Cuban innovation survey also mentions that there had been many innovations and rationalisations in the sugar industry that had generated economic benefits (ONE, 2010). It is possible that these are more incremental, judging by the name, but also due to the lack of patents related to these types and amount of innovations indicated by the survey.

The different institutional arrangements and cluster externalities can complement each other, and a mix of arrangements is beneficial for

innovation. For the development of innovation and economic growth it is beneficial to have a broad base of basic scientific knowledge that explains how and why things work as they do, and applied science and engineering knowledge that suggests how the basic knowledge can be used to address specific needs. It also requires systems that promote the diffusion of this knowledge and the possibilities of access to it (Mokyr, 2002b), as well as knowledge about demands and possibilities to carry out innovation, as a response to needs (Mokyr, 2002a). It is also important to have proper incentives to develop new technology, and there should be many actors that have the possibilities to formulate and channel their needs and not block the appearance of innovations. If there is a broad range of institutional arrangements in institutionally thick places, as many clusters are, it is likely that there will be greater opportunities for finding important components for innovation, more ways of channelling needs, and more means for organising activities, all of which should be conducive to innovation. Much of the needs come as signals through market mechanisms, but there is also a role here for state arrangements, to identify and channel needs of resource-poor groups, whose needs are harder to signal through price mechanisms, as well as from different kinds of networks like NGOs that could identify and channel problems of negative externalities such as environmental problems or labour rights. The most innovative of the clusters in the cases is São Paulo, which also has the broadest set-up of actors and institutional arrangements in place. At the same time, a mix in itself does not guarantee a positive outcome; it can also generate negative effects, such as vested interests, influencing state arrangements to support them, which is negative for the overall society.

Irrespective of the types of institutional arrangements in place, there is a constant pressure for change and over time most practices become outdated and give way to new ones. For clusters to be long-term supportive of innovation there is a need for mechanisms that enable long-term continuous change, allowing for the creation and implementation of new technologies, and weeding out poor ideas. As there is no certain knowledge about future development, the most long-term resilient systems are the ones operating with broad set-up of arrangements, with a plurality in organisations and solutions, with tolerance for trial and error (North, 2005). In clusters with little diversity in their co-ordination mechanisms there are fewer capabilities in adapting to new circumstances and less resilience to risky environments

(Hollingsworth, 2000). With a variety of institutional arrangements, there is incoherence in governance, but it provides capabilities for adaptation (North, 2005). In the short term this can be less efficient than a thoroughly controlled society, but in the long term it will generate more innovations. Cuba was very successful early on in upgrading the sugar industry and creating growth. Over time, though, its system has proven non-sustainable and despite many political efforts to restart the sugar sector, it has failed.

The development economist William Easterly (2010) has identified that for foreign aid it is hard to foster development by implementing solutions top-down, as these are often decontextualized and lacking in feedback mechanisms and accountability. This could also be argued to be a problem of authoritarian states like Cuba, where there is a lack of feedback mechanisms. For top-down solutions and implementation of external best practices to work there is a need for local interaction and feedback. Easterly has suggested that true development occurs when there are problem-solving systems in place that can both facilitate bottom-up processes and incorporate top-down projects: *“the market is a decentralized (private) problem solving system with rich feedback and accountability. Democracy, civil liberties, free speech, protection of rights of dissidents and activists is a decentralized (public) problem solving system with (imperfect) feedback and accountability. Individual liberty in general fosters systems that allow many different individuals to use their particular local knowledge and expertise to attempt many different independent trials at solutions. When you have a large number of independent trials, the probability of solutions goes way up.”* Well-functioning systems match private returns to social returns; markets do this with private goods, and political systems can do this for public goods, where political actors are rewarded when their actions match the social returns. Problem-solving systems can use best practises, but adapt them to the local context. A strong research system can be an important part of this, together with a system that allows for both private initiatives to create innovative solutions to problems and state solutions to address public problems. Clusters that are broad in actors and arrangements could possibly be seen as places that are partial problem-solving systems for their specific economic activities.

Clearly the mix of institutional arrangements and the interplay between them will affect the ways in which clusters can be conducive to innovation. The different arrangements have their advantages and drawbacks, and for a cluster it seems beneficial to have a broad mix of arrangements in place.

6.2 Outcome in Cases

The clusters in our cases differ with regard to institutional set-up and institutional arrangements, and so do the cluster externalities and the innovation performance. Furthermore, the role of cluster externalities for innovation differs between the cases. The case where cluster externalities are the most important is São Paulo, whereas the cluster externalities are less important in Cuba and in the North East of Brazil. In these locations the concentration of people in the sugar clusters is rather a problem. In São Paulo there are institutional arrangements and cluster externalities that provide incentives and enable and constrain innovation, In Cuba, broadly speaking, there are arrangements that can enable and constrain innovation, but do not provide incentives, whereas in the North East of Brazil there are arrangements and externalities that give incentives and constrain innovation, but there are fewer enabling arrangements in place.

São Paulo is the strongest case, with a broader mix of arrangements present and the greatest role for markets and networks that are more oriented towards joint action, addressing common problems and innovation rather than protecting incumbents. The innovation outcomes in São Paulo seem to benefit from the cluster. There are strong private, public and network-based scientific and technology capabilities, specialised suppliers, and connections to related industries. There are also strong factor markets of specialised labour and venture capital. The current interplay of actors and arrangements seems beneficial for innovation. There is more innovation coming out of São Paulo than the other cases, but also more than there was in São Paulo before the reforms of the 1990s. There are tendencies to congestion, related to infrastructure and high demand for skilled labour, that are also being addressed by both state arrangements and network arrangements. There are strong firms that develop new knowledge and innovations that are diffused to suppliers and are conducive to user-producer learning. There are state arrangements that enable education, R&D, reskilling, market opportunities, and regulation that addresses environmental concerns. Furthermore, through *Pró-Álcool*, the state fostered much of current capabilities, in sugarcane growing and processing equipment for the ethanol and sugar industry. Furthermore, networks currently seem to be less about the protection of incumbent positions to prevent newcomers and technologies than was the case before the changes of the 1990s.

The North East has shrunk and it has fewer suppliers and research resources than São Paulo. The size of the cluster was boosted by protective state arrangements and it expanded beyond sustainability and has struggled with restructuring when much of the protective measures were removed. Local networks seem to be less important for innovation, and more geared to addressing common problems such as infrastructure, but also lobbying for protection. The local market is smaller than in São Paulo and the focus is on exports. There are mills and sugarcane growers, but few new innovative firms or local producers of process equipment. The cane growers and millers are implementing new technology and purchasing equipment from suppliers in São Paulo. There is a greater focus on innovation as market arrangements have become more important. There is also slightly more division of labour than before the 1990s. Yet there is less division of labour and user-producer learning in the North East than in the Centre South. The innovation in the North East is less due to cluster externalities than due to international and national relations. The North East could benefit from more enabling arrangements, such as network or state arrangements for innovation that could proceed from the local context, such as technology for mechanical harvesting in hilly terrain, and cane varieties optimal for the region. The setting up of networks like APLA could be beneficial for these processes to train linkages, which should be possible as trust in the cases has been built through repeated interaction in professional relations. A project like the technology road mapping in São Paulo could also be beneficial, as a means for building trust and identification of problems/opportunities. There is also need for more educated and trained people.

Cuba has a broad institutional mix of actors, but not of arrangements. Despite this there have been innovation and upgrading, both product and process innovations, with technology developed for a large range of derivatives and there are interesting diversifications into bio-tech. The driver behind this is state arrangements that have enabled specialisation through research institutes and education of labour and knowledge spill-over and locally through the quasi hierarchies around the refineries. State arrangements have also increased specialisation of the industry through upgrading schemes. However, local cluster externalities have been less important for innovation. Another important factor has been international demand, i.e. first the US, then the USSR and lately Venezuela. Good technology is generated in Cuba, but the mechanisms for channelling knowledge about needs and

requirements are poorer, as is the organisation of transactions, leading to Cuba being rather good at producing technology and inventions but not long-term productivity raises. The sugar cluster in Cuba, due to a lack of market mechanisms and a lack of price signals, grew through extensive practices, with sugar production rising beyond sustainable practices. It seems to be the counter-case to Schumpeterian competition (1934), where firms with innovations beat the ones who are only efficient producers. In the Cuban case the actors, despite technological capabilities, lose out long-term, due to organisational problems. Furthermore, there seems to be political ambivalence towards the sector that limits possibilities, and conflicts of political interests which block certain activities that could develop the cluster; examples are diversification into ethanol and foreign investment. There ought to be a great potential for the industry in Cuba, as there is much idle land, good natural conditions, a good knowledge base in the area, and close locations to foreign markets. At the same time, Cuba itself has great energy needs and has been going through a long energy crisis. The production of ethanol could possibly reduce these problems. There is also a supplier industry of machinery and process equipment that could benefit from a revitalised sugar cluster, as well as some mills that have been producing different types of derivatives that could potentially bloom. Cuba has already begun to sell consultancy services based on its strong S&T resources, and this is something that could probably be further developed. Cuba is at the moment going through economic restructuring, the outcome of which is unclear. However, the sugar cluster would need more market mechanisms and local network arrangements to revitalise.

6.3 Implications for Policy

The policy implications of this study are first and foremost that clusters are idiosyncratic and differ with regard to institutional set-up, and this has implications for how clusters can be expected to have an impact on innovation. The cluster externalities can work at different levels, at which they provide incentives, enable or constrain innovation. The institutional arrangements are forms that influence arrangements differently; in some cases the externality comes out of particular arrangements, whereas in other cases it prevents it. For a policymaker it can be an approach to analyse a cluster with regard to what kinds of arrangements are in place and to what

extent externalities are taking place, and from this identify different policy measures, such as initiating a deliberative cluster platform, or trying to stimulate more competition, reducing complexity for firm start up, retraining labour to increase specialisation, etc.

At the same time, it is very difficult, if even possible, to engineer a dynamic cluster through a top-down process; see the challenges in Cuba with political campaigns and also with restructuring in the 2000s. This is not only due to the problems of planning, but also because institutional arrangements and cluster externalities have both positive and negative sides for innovation, and it is hard to estimate the outcome of the interplay of the arrangements and externalities. Yet this is a process that policymakers have to engage in and are forced to act upon, either by abstaining from action or by introducing active measures to enable innovation, overcome constraints or provide incentives for innovation.

In all of the cases state arrangements have been successful in enabling specialisation in clusters, by provision of education, research and specialised services. It has also been possible to stimulate knowledge spill-over through interaction between research institutes and industry, as in Cuba with the research institutes, and educated labour bringing new skills to industry, and in São Paulo through support to firm start-ups. This is an area where state arrangements seem to have an important role to finance education and long-term research, but also to facilitate knowledge diffusion.

Besides education and mixed industry/research institute projects, one way of stimulating knowledge diffusion is through different networking and linking activities, through dedicated platforms. These platforms can be set up for specific challenges, but there can also be more broadly based deliberative platforms, such as the cluster initiative APLA in Piracicaba. However, even though state arrangements are the type of arrangements with the most possible powers, the state is not in a position to manage all of activities in a cluster. Clusters are not only the networks, but are broader than this, and there are different policy measures that can address different areas. Introducing cluster initiatives should not be seen as policy projects that will steer and control cluster processes, but rather as tools to identify problems and opportunities and address these, and different actors have different responsibilities, as they have different means to act and influence innovation.

When setting up different networks, it is important to beware of the danger of their turning into rent seeking networks with the objective of preventing new firms and technologies. The initiatives should not only focus on existing firms and technologies, but also on emerging areas, and should not be overly strict about which economic activities to include, but possibly involve actors with knowledge bases further away to stimulate innovation. At the same time there is a trade-off with actors at further distances, as the cognitive distance may be more costly to overcome, and collaborative power will be lost. In addition, it is important not only to have SMEs involved in projects, but to include dominant firms as these are the ones with influence and resources enough to have an impact.

State arrangements also influence innovation in clusters with regard to regulation of markets and new firm start-ups. Cuba is clearly in need of more markets that can channel signals of demand and allocate resources to more innovative firms and also weed out poor practices. There is also a need for more new firms that are allowed to grow and for interaction in different types of networks. In Cuba there are already market and network arrangements present, but these are acting in the informal economy; instead of suppressing them, state arrangements ought to embrace them, since much of these activities are what keeps people afloat. In Brazil the introduction of more market-based arrangements has led to increased innovation activities. At the same time there are some indications that Brazil could improve measures for firm start-ups, as according to World Bank rankings they are way down in position 129 when it comes to how easy it is to start a firm.

The public sector not only provides incentives and is the ultimate enforcer and upholder of the regulatory system, but is in many places also the provider of a number of services, such as education, transportation and health care. The public sector can both be an innovator in these sectors and stimulate clusters through user-producer learning by outsourcing of services, procurement of goods and prescription through regulation.

Another important area for state arrangements is an overall view of how different sectors and systems function. With the growing worries about environmental problems it has become increasingly popular in innovation policy circles to discuss grand challenges and system innovation, where the role of the public is to co-ordinate and introduce efforts to address problems of systemic scale that no actors can manage by themselves. To achieve such a

system transformation there is a need to address many levels and sub-systems, and here policy has an important role, as there is no other actor in a position or with the responsibility to manage these types of processes. To facilitate such change it is necessary to develop new technologies and alter legislation, infrastructure and user behaviour (Elzen et al., 2004). The *Pró-Álcool* programme can be seen as an interesting example of a system innovation programme that worked on many different levels in order to achieve system transformation, by implementing a number of state arrangements, but also by influencing networks and market arrangements. It has been crucial to develop capabilities and to create necessary linkages between industries, research institutes and public authorities in the technology, industrial policy, energy planning and agricultural production areas. Ethanol production has increased 30 times, yield per hectare by an average of 60%, and production costs have fallen by 75% (Nass et al., 2007). The programme has benefited all of Brazil, but possibly São Paulo most of all. São Paulo was already more advanced than the North East with regard to diversification of the economy and research capabilities, and both regions altered their production output with radical increases in ethanol output, but this did not generate any greater diversification in the technology base in the North East, and most of the new capabilities are with firms in São Paulo that also provide the North East with process equipment.

In clusters problems can emerge such as congestion, negative externalities of environmental problems, infrastructural and cognitive lock-in. State arrangements are in a position where they can introduce measures to overcome these problems that can constrain innovation, through activities such as basic research, e.g. into new sugarcane varieties, improved machinery for mechanical harvesting and new derivatives from ethanol. The state can improve infrastructure and create incentives through legislation, such as the prohibition on burning cane.

One approach to address problems of congestion and lock-in is to involve networks, to identify problems and solutions in clusters, with the caution mentioned above about vested interests. One should avoid simply taking best practices from other contexts, and trying to introduce them into the new context and then paying lip service to bottom-up processes, by already having specific expectations of stakeholders in mind. Instead there should be processes of co-development, proceeding from the local context, and foreign examples can be implemented in the local context.

If the state introduces measures to support firms it should avoid practices that reduce incentives for innovation or that foster non-sustainable bubbles. In our cases it seems as if the protection of practices of stimulation in the North East of Brazil and Cuba fostered clusters that grew out of proportion, and with non-competitive practices that suffered severely when the threshold was passed and there was a forced need to restructure. State arrangements could rather aim to establish systems that stimulate flexibility and allow for continuous change, with regulation and measures that support new firm start-up but also enable reskilling and education of labour through social security and education systems. When restructuring clusters or providing support to upgrading in clusters, as in Brazil with mechanisation, there is objection by labour due to fear of loss of income. This problem was removed in Cuba, due to social security measures. At the same time the social security measures should not prevent flexibility by locking people into aid dependency.

It is commonly argued in innovation policy discussion that there is a need for better coordination of actors (Cassiolato et al., 2003; Koeller and Gordon, 2008) and there are good examples of national coordination, such as *Pró-Álcool*. The sugar and ethanol clusters in São Paulo have been able to coordinate activities and generate innovations, new industry capabilities and scientific capacity in a systemic fashion. At the same time there is a danger that through alignment actors may lose independence and become distracted from core activities, which in the long turn will reduce the possibilities for contributions to the system, such as by steering universities to focus on present industry needs rather than more long term knowledge, or make universities lose their role as an independent critical voice. There is need for knowledge developed that is geared towards specific local needs, but there is also need to develop knowledge that is beyond present practices and scopes in order to move cluster frontiers.

Finally, in discussions about clusters and the relation to innovation, people often tend to discuss this as a question in terms of either/or: either one should opt for stimulating only clusters or not. Some argue that all countries need to specialise to further develop their technological advantage, and that clusters are important for this; others claim that it is important to reduce risks through diversification schemes and that through the combination of divergent knowledge bases, truly innovative solutions can be generated, that the so-called Jacobs spill-over is more important than the MAR spill-over. I

can see the value of both approaches, and would opt for the argument that there are no silver bullets; clusters have a value, but they are not the unique way forward for an economy. Neither are they a prerequisite for innovation; this will take place even without clusters. The discussion is similar to the one on ethanol as a biofuel. Some argue that it is not a viable solution, as it will never be able to solve the world's entire energy problems, as there is not enough land to grow ethanol to replace all the petrol. In my view this is a rather high requirement of a technological solution, as it has never been demanded of any previous energy source to be the only one. For mobile devices we have for a long time had petrol, diesel, gas and electricity, for example. Likewise, I would say that ethanol as a biofuel is one part of a sustainable energy mix, and in a dynamic economy there will most likely be clustered economic activities and non-clustered ones.

6.4 Generalisations and Limitations

My ambition has been to explore how institutional arrangements affect cluster externalities that have an impact on innovation – in my cases of the sugar clusters in Brazil and Cuba – and to explore whether the effect of institutional set-ups on cluster externalities can explain the innovation outcome in the cases. The empirical material has been used to identify and describe mechanisms that are of general interest to cluster theory and not only applicable to Cuba or Brazil or to sugar clusters. However, there are a number of factors worth reflecting upon with regard to the empirical data, for the possibilities of general validity of the findings presented here. In the next sub-section on future research I present a number of ideas in order to address some of these topics of caution.

It is a challenge to delimit clusters, both from a geographic perspective and an economic-activity perspective. In this study a heuristic approach has been used, with the view of clusters in the discussion hovering between sub-regional clusters like Piracicaba and state-size clusters like São Paulo and Cuba, to allow for more explanatory powers. It is likely that some of the mechanisms and cluster externalities function on a larger scale, whereas others are more relevant only on a narrower scale. It has not been the ambition of the thesis to explore this issue, but it could be a future research project. The findings here do not give any guidance as to which geographical

scale the externalities occur at or not, or about limitations with regard to economic activity or critical mass.

When working with data on high levels of abstraction and consisting of aggregated components, there is also a challenge to relate this to aggregated output indicators, in order to find causality. For example, the category of network arrangements could easily be broken into a number of other categories, such as alliances, associations, communities, informal and formal networks, open networks, closed and focused networks. There may be differences with regard to influence on cluster externalities due to these forms. Likewise here state arrangements aggregated are from federal, national, state, regional and local levels and one could also differentiate state arrangements into legislation, financing and service provision. Furthermore, there are also differences in how a democratic state operates and how an authoritarian one does. Here there definitely are differences. In a similar fashion the cluster externalities are aggregations of sub-effects; for example, the category of knowledge spill-over consists of sub-components such as new firm start up and informal networks, where there may be differences with regard to connections to different arrangements, e.g. networks may serve informal knowledge sharing, but prevent new firm start up. Still, for this study it has served its purpose to make aggregations, in order to explain that different institutional arrangements in clusters will have an effect on how clusters influence innovation. With more complexity the explanatory power could have been lost. The approach of this study has been both to combine more quantitative data that can give guidance about direction and possible relations between different indicators, and to complement this with qualitative data to explore more causal explanations to these relations. At the same time, the aim of this thesis is both narrow and extremely broad, with limitations in time and space to what can be explored. The possibilities to generalise the findings would increase with more qualitative studies where more in-depth knowledge is generated, for example, by innovation histories that follow single innovation and entrepreneurs to find out the role of different cluster externalities and arrangements in the innovation process. Likewise, it would be beneficial to make more quantitative studies, exploring both more complexity in data categories and a greater number of cases.

One could also question how well the case of Cuba can be used in a cluster context, where the ideas and theoretical build-up around the cluster concept originates from market economies, and the examples of markets and

networks are very limited in the formal Cuban economy. At the same time, I would argue that it is well grounded for the purpose of this thesis, as it provides great explanatory power of the role of different arrangements for cluster externalities and the influence on innovation.

However, as compensation for this factor, this thesis has compared two cases in Brazil and their change over time. At the same time, the findings can be improved by comparing with other cases and other settings, such as more developed economies, and here an interesting case could be Australia, which also has a notable sugar industry, and which removed its agricultural subsidies at the start of the 1990s and deregulated its economy; likewise it could be interesting to compare with Germany and the USA, with agricultural support and protection and the outcome in different states in these federal nations.

There are also possibilities that there are differences in cluster externalities depending on the connection to where in the technological life cycle the cluster exists, whether it is in early phase, maturity or decline, and to explore the importance of different arrangements for different phases, it is possible that it can be more important to have some types of arrangements such as markets and networks early on when there is a search phase, and in later phases when there is more optimisation and efficiency orientation, quasi hierarchies are more relevant, and in periods of decline, there may be a need for state arrangements to break lock-ins.

Another aspect which is a challenge is how much innovation and long-term productivity stem from cluster factors, and how much from other factors. There are many other factors that are important, for example, capital endowment, natural resources such as appropriate land and a proper climate, and national and international relations as well. Some of these other explanatory factors can be removed by comparing the cases over time, as some of these local explanatory factors that are beyond the institutional set-up of the cluster remain the same over time.

6.5 Future Research

During the work with this thesis a number of further questions have arisen. In this thesis both intensive and extensive data has been used, and it balances

very abstract phenomena on a highly aggregated level. It would be desirable to explore the relations both more extensively and more intensively.

A first approach, though, could be to compare with additional cases, with other types of arrangements in place, such as a cluster in an even more market oriented economy and cases from more developed economies, for example, sugar clusters in the US, Australia, Denmark, Germany and France. Furthermore, longitudinal studies could be conducted of cases with radical institutional shifts; here again Australia could be interesting as it radically deregulated its economy and removed agricultural subsidies at the beginning of the 1990s. One could also explore what is the outcome of differences at state levels in more federative states, where there may be great differences in institutions at state levels, e.g. the US and Germany. In the Dominican Republic there was a restructuring programme in 1999, when all sugar mills were privatised, with diversification of sugarcane land and an emphasis on sugar by-products and derivatives; a similar approach has been carried out in Trinidad and Tobago in 2003. In Thailand the sugar industry has been able to adapt to world markets, but has not upgraded; there are studies implying that it is because there are institutions that support the first process, but not the latter (Alvarez and Perez Lopez, 2006). In addition, one could explore different industries, such as more consumer- or service-oriented industries and also different periods in the technology life cycle.

At the same time, it could be worthwhile to go in more depth, to examine a number of innovation histories or trajectories where a number of entrepreneurs and innovations are followed, and explore the role of different organisations and institutional arrangements allowing these to occur. This could generate better understanding of the mechanisms in the cluster, to better tie the institutional arrangements and cluster externalities to innovation. This could be complemented by a more strictly quantitative approach, using OECD-based innovation survey data like Pintec or CIS (Community Innovation Survey) data, together with data on firms and employment. This could possibly generate more knowledge about differences in innovation outcome.

This project has a highly aggregated and abstract level for the phenomena explored; one could potentially disaggregate the phenomena even more to make a richer weave to study. The current cluster externalities are composed of two or more sub-components through which they influence innovation.

These could be separate and explored separately; e.g. knowledge spill-over comes from new firm start-up and from informal networks. Likewise, one could differentiate the institutional arrangements more, e.g. networks into alliances, associations, communities and communities of practice. State arrangements can be explored from different levels, such as federal, national, state, region or local level, and can be differentiated into arrangements such as legislation, organisations, service provision and attitude influencing.

The project itself has generated other ideas related to innovation. One idea is related to the importance of flexibility and interoperability to reduce uncertainty and risk for people investing in new technology, well exemplified by the breakthrough of the flex car, which would be an interesting symbol and point of departure for a study on innovation. Likewise, it would be interesting to analyse and describe the Pró-Álcool programme from a systems-innovation perspective.

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Interviews

Piracicaba and São Paulo Brazil

Amaral, Weber	CEO	Polo Nacional de Combustivles,	30/11/2006 16/04/2008
Andrade, Tadeu	Diretor Pesquisa e Desenvolvimento	Centro de Tecnologia Canaveieira (CTC)	15/04/2008
Barbosa, Sergio Marcus	Gerente	ESALQTEC – Incubadora de Tecnologia	29/11/2006
Burgos, Pedro	Assessoria de Comunicação	SEBRAE São Paulo	28/11/2006
Calil, José Francisco	Secretary of Economic Development	City of Piracicaba, Municipal Department of Economic Development	15/04/2008
Castelar, Flávio	Manager	APLA Piracicaba	15/04/2008
Cavalheiro, Sueli	Assessor Especial	Governo do Estado de São Paulo, Secretaria de Desenvolvimento.	18/04/2008
Cavalieri, Mel	Assessoria de marketing	SEBRAE São Paulo	29/11/2006 14/04/2008
Ellen Cordeiro de Rezende,	Assesora	UNICA	27/11/2006
da Costa Barros, Debora	Assesora	Prefeitura do Municipio de Piracicaba	29/11/2006
Correa, Ivan Ferraz	Eng. Comercial	CSJ Metalúrgica	17/04/2008
Estacio, Rose Mary	Gerente U.O.	Desenvolvimento Territorial SEBRAE São Paulo	28/11/2006 14/04/2008
Ferraz Alvares Dias, Maria Beatriz	Assesora	SEBRAE São Paulo	28/11/2006
Freies, Osvaldo de Souza	Gerente U.O.	Desenvolvimento Territorial SEBRAE São Paulo	28/11/2006
Goulart de Miranda, Jose Marcelo	Analista	Innovation and Technology Unit, SEBRAE Federal	03/12/2006 05/12/2007 2010 (email)
da Graça D. Fonseca, Maria	Professora Doutora	Universidade Federal do Rio de Janeiro (UFRJ)	04/12/2006
Mazzoldi Soriano, Jose Roberto	Assessor de Gabinete,	City of Piracicaba, Municipal Department of Economic Development	15/04/2008

Ribeiro, Antonio Carlos de Aguiar	Gerente, E.R.	Piracicaba, SEBRAE São Paulo	29/11/2006
Roque de Oliveira, Enio	Assessor Técnico	Orplana, Organização de Plantadores de Cana De Região Centro-Sul do Brasil	16/04/2008
Santos Tavares de Almeida, Luciano	Secretário de Indústria y Comercio and Secretário Adjunto	Prefeitura de Piracicaba and Governo do Estado de São Paulo, Secretaria de Desenvolvimento.	29/11/2006 18/04/2008
Sartori, José S.	Comércio Internacional	CSJ Metalúrgica	17/04/2008
Scarso, Homero	Gerente Regional	CIESP	01/12/2006
Stipp, Eugenio	Consultant	Prefeitura/Agenda 21	01/12/2006
Storel, Antonio	Assessor	The National Agency for Land Reform (INCRA, Instituto Nacional de Colonização e Reforma Agrária)	27/11/2006
Vian, Carlos Eduardo de Freitas	Professor Doutor	Universidade de São Paulo, Escola Superior de Agricultura “Luiz de Queiroz” (ESALQ)	01/12/2006
Zylberstajn, Decio	Professor Titular	Universidade de São Paulo, Faculdade de Economia, Administração e Contabilidade (FEA/USP)	27/11/2006

Pernambuco & Alagoas, Brazil

Cavalcanti, João Alexandre Lira	Coordenador da Unidade	SEBRAE, Pernambuco	03/12/2007
Almeida, Cicero Augusto B.	Gerente Agrícola	Usina Coruripe Matriz	06/12/2007
Andrade, Arnobio	Secretário Executivo de Tecnologia, Inovação e Ensino Superior	Secretaria de Ciência, Tecnologia e Meio Ambiente, do Governo do Estado Pernambuco	03/12/2007
Arruda Laprovitera, Ana Cláudia	Analista	Unidade de Apoio Gestão Estratégica, SEBRAE, Pernambuco, Brazil	03/12/2007 and 07/12/2007 2010 (email)
Bezerra, Laedson	Coordenador	Recife, SEBRAE, Pernambuco, Brazil	04/12/2007
Correia, Roberta de Melo Aguiar	Coordenadora, Unidade de Apoio Executivo	SEBRAE, Pernambuco	03/12/2007

Cortez, Alfredo D. Villela	Assesor da Directoria	Sindaçúcar Alagoas	05/12/2007
Dubeaux Torres, Vera Lúcia	Professora Doutora	Universidade Federal de Alagoas, Unidade Academica Centro de Ciencias Agrarias, (PMGCA-UFAL, RIDESA BRAZIL)	05/12/2007 and 06/12/2007
Evangelista Bezerra Filho, David	Economista	Sindaçúcar of Pernambuco	07/12/2007
Piros Kovacs, Erica	Analista	Unidade de Apoio Gestao Estratageica, Carteira de Industria, SEBRAE, Pernambuco, Brazil	03/12/2007 and 07/12/2007 2010 (email)
de Moraes e Silva, Ronaldo	Gerente	Unidade de Territorios Especificos SEBRAE, Alagoas	05/12/2007
Moreira, Ricardo	Analista	SEBRAE, Pernambuco	03/12/2007
Morais de Andrade Lima, Alexandre Araujo	Diretor Presidente,	Associação dos Fornecedores de Cana de Pernambuco (A.F.C.P)	04/12/2007
Neto, Jaime	Gerente	Grupo JB	04/12/2007 2010 (email)
Passos Ferreira, Sergey Sacha	Gestor do APL	APL Tecnologia da Informacao SEBRAE, Alagoas	05/12/2007
de Santana, Maria Josenalda	Política Salarial	A Federação dos Trabalhadores e Trabalhadoras na Agricultura no Estado de Alagoas (FETAG Alagoas)	06/12/2007
Simões Neto, Djalma Euzébio	Coordenador Geral	Experimental station of Carpina Universidade Federal Rural de Pernambuco - UFRPE) Carpina, Pernambuco	03/12/2007
Wanderley, Cecilia	Diretora Tecnica	SEBRAE, Pernambuco, Brazil	07/12/2007

Cuba

Dr. Alvarez Delgado, Amaury		ICIDCA, Instituto Cubano de Investigaciones de los Derivados de la Cana de Azucar	23/10/2007 18/02/2008
Caballero, Frank	Manager Distillery	Central Hector Molina,	19/02/2008
Dr. Perez Villanueva, Omar Everlyn	Economista	Centro de Estudios de la Economia Cubana (CEEC)	25/10/2007 21/02/2008
Fernandez Dominguez, Pablo	Official at Sugar division	Ministry of Industry, Sugar Division	09/02/2006
Dr. Galvez Taupier, Luis O.	Director General	ICIDCA, Instituto Cubano de Investigaciones de los Derivados de la Cana de Azucar	23/10/2007
Dr. Garcia, Anicia	Profesor e Investigador	Centro de Estudios de la Economia Cubana (CEEC)	08/02/2006
Leon Gimenez, Lazaro	Director	UBCP	19/02/2008
Martinez, Arsenio	Director	Central Hector Molina	19/02/2008
Mondeu Gonzalez, Ruben	Director ICT y especialistas,	Instituto Cubano de Investigaciones Azucareras	25/10/2007
Dr. Monreal, Pablo	Profesor e Investigador	Center for Research on the International Economy (CIEI)	07/02/2006 24/10/2007 20/02/2008
Dr. Nova Gonzalez, Armando	Profesor e Investigador	Centro De Estudios de la Economia Cubana (CEEC), Universidad de la Habana	10/02/2006 23/10/2007 18/02/2008 2010 (email)
Sao Pensa, Margarita	Directora Ciencia y Tecnica,	MINAZ, Ministry of Sugar	25/10/2007
Torres, Alfredo	Investigador	ICIDCA, Instituto Cubano de Investigaciones de los Derivados de la Cana de Azucar	23/10/2007 18/02/2008
Torres, Hermes	Jefe recursos humanos	Cooperativa UBCP	19/02/2008

Appendices

Appendix 1: Cosan

Cosan is one of Brazil's market leaders among sugar and ethanol companies. The company has 23 mills, and has a diverse portfolio of products on offer: sugar, ethanol and electricity. They generate electricity from sugarcane bagasse in ten co-generation plants. Total annual sales of fuels amount to 18 billion litres and they have a retail network of about 4,500 retail sites.

Cosan was founded in 1936, when it built the Costa Pinto mill in Piracicaba (São Paulo State). In the 1980s it began an expansion process based mainly on acquisition of other companies located in the State of São Paulo (Cosan, 2010). In 1986 they began exporting sugar, when a federal law was dropped that prohibited other mills than the ones located in the North East from exporting. In 1993 they developed a new variety of sugar for export, VHP (Very High Polarisation). They were also developing new ways to export bulk sugar, which provides logistical gains. In 1996 they received concessions in Santos for a port terminal, which has been key to sugar exports. In 1997 they started working with outsourcing of sugarcane production and formulation of requirements, increasing focus on production and trading of products. In 1999 they formed a strategic partnership with British sugar group Tate & Lyle, which takes a 10% stake in the port terminal. In 2002 they formed a strategic alliance with France's Sucden and Tereos (in 2007 Tereos gave up its 6.2% stake in Cosan, though). In 2002 they launched the SóCanaPura programme, resulting in productivity gains in the agricultural and industrial areas and also began working with geo-processing technology and use of satellite images to monitor crops.

In 2005 they formed a partnership with Crystalsev, Grupo Nova América and Cargill to open an ethanol export terminal in Santos. They also formed a partnership with China's Kuok group. In 2008, Cosan, together with a large group of mills, created the company Uniduto, to take care of logistics of ethanol. The company will have a system of pipelines, storage units and port facilities for transportation and export of ethanol.

From 2005 onwards a number of firms and brands have been acquired, such as Mundial, Destivale, Benálcool, Bom Retiro, União brand (retail market leader) and the Dolce, Neve and Duçula brands. Cosan has also acquired Esso's Brazilian fuel production and distribution, including the licenses to use the Esso and Mobil brands in Brazil. This has been a step in a process to become a complete provider of ethanol (Dobosz, 2009). In 2009 they incorporated NovAmérica's industrial, commercial and port units. With these acquisitions it has become the first vertically integrated company in the industry.

This consolidation process has been followed by a joint venture with Shell that will produce and commercialise ethanol and power from sugarcane and distribute a variety of industrial and transportation fuels through a combined distribution and retail network in Brazil. It will also explore business opportunities to produce and sell ethanol and sugar globally. They will also invest more resources to increase output. Into the new joint venture Shell will also add a Canadian subsidiary that is focusing on developing a technology to make ethanol from straw (Economist, 2010a). The proposal is awaiting regulatory approval.

Appendix 2: Dedini Indústrias de Bases A/S

Dedini was founded in 1920 in Piracicaba, where they still have their headquarters. They have six units in other areas of the country, such as Sertãozinho (SP), Maceio (AL) and Recife (PE). The firm began in the sugarcane industry and it is still a leading activity, but there are also activities in other industries. Today it is one of the world's largest manufacturers of complete plants and they work actively developing new technologies, such as rapid hydrolysis and plants for production of bio-diesel (Inovação Unicamp 2007).

The company began in a blacksmith shop in 1920 and in 1922 it was diversified into service provision, by manufacturing and repairing mills, boilers and other equipment. It was the same era as the coffee crisis in São Paulo, when the sugar industry began to grow in the state. In 1939 they had reached a position where they were serving almost all the mills in the country. They also manufactured their first complete equipment for sugarcane power plants, a set of mills for Nossa Senhora Aparecida, and the

subsidiary Codistil was founded that constructed distilleries. In 1992 an Alliance with the company Zanini was formed in the form of DZ Engineering, Equipment and Systems, which became the world's largest provider of equipment for the sugar and alcohol industry (Dedini, 2010).

Dedini has provided equipment for 120 complete factories and builds around 12 new units per year. The units designed and assembled by Dedini stand for 80% of Brazilian production of alcohol and approximately 25% of world production. They have sales representatives in South America, Central America, North America and the Caribbean and do business in South America, North America, Central America, Caribbean, Asia, Oceania and Southeast Asia. The composition of exports from Dedini is dominated by equipment, rather than knowledge, but in some cases they deem that the costs of producing locally and exporting is not worthwhile, and in these cases they produce locally in the place for the export, together with local partners. For wealth generation they consider it better to export equipment than knowledge. At the same time they have a strategic interest in building a global market for ethanol and see the need for exporting knowledge to establish ethanol as a global commodity (Inovação Unicamp, 2007).

Dedini is R&D-intensive, even though they operate by customer-driven engineering needs, creating unique solutions. Dedini is organised in different divisions that each have their own sales departments, engineering and contract administration. They work with knowledge development in three levels of engineering: i) process and basic engineering, ii) detailed and manufacturing engineering and iii) industrial and manufacturing engineering. They have proprietary technology, but can also license technology from third parties, as well as develop technology jointly with partners. Whether to use proprietary technology or to license is dependent on the market situation and potential, their own technological capabilities and how close they are to the state of the art of technological knowledge (Inovação Unicamp, 2007).

In their division of Sugar and Ethanol they have a specific organisation for research and development consisting of two interacting units, but with specific programmes: i) engineering of sugar and alcohol, which works close to the market and defines what will be made or offered to customers, and ii) engineering development that works with developing new technology. The engineering team consists of 30 persons who develop a portfolio of strategic

projects in partnership with FAPESP. It does not work exclusively with these projects, but is also involved in other projects (Inovação Unicamp, 2007).

Dedini accumulates knowledge from every project carried out, and parts of this knowledge are applied in new projects. If there are patents as outcomes of certain projects, these rights have to be respected if they are to be used in other projects. According to Dedini, knowledge in the sugar industry has not traditionally been patented much. In 2007 they had ten patents granted, two applications published and seven others in preparation (Inovação Unicamp, 2007).

Dedini is also fostering collaboration with universities and research institutes. Direct collaboration began with the development of Dedini Rapid Hydrolysis (DHR). In 1986 they initiated a project to develop an acid hydrolysis process for the extraction of cellulose from sugarcane bagasse, which is a way of producing ethanol more efficiently that will allow for the use of leaves and other residual products when producing ethanol. Dedini's process is also very rapid; it takes one hour compared to similar solutions which can take up to 72 hours (Inovação Unicamp, 2006d). The Dedini process has involved acids and high pressures, whereas competitors have used enzymes to break down the biomass of the cane. Later Dedini began to explore a combination of acids and enzymes. The process in itself is not new, but how to operate it efficiently is. When fully industrialised it is expected that with this process technology the current alcohol production per hectare of harvested sugarcane will be doubled, and ethanol will be able to compete with petrol prices of USD 20/barrel compared to USD 35/barrel today (Oliverio and Proença Hilst, 2003).

They kept the project in-house until 1996, when they patented it. The year after, a contract was signed with CTC to study inhibitors of the process and to set up a pilot plant. Dedini led the project and carried out most of the research, but involved CTC and university resources to carry out research on specific parts of the process, such as characterisation of bagasse and hydrolyzate lignin, a by-product of the process. ESALQ explored the development of fermentation, and in later years Unicamp and UNICA studied fermentation flocculant. The pilot plant was transferred to CTC to address problems with the pre-treatment of the hydrolyzate. They worked in the CTC plant until 2002, when the process was transferred to a semi-

industrial plant in the St Louis Mill of Dedini Agro. This was a division with land and mills focusing on production of sugar and ethanol. In 2007, this division was sold to the Spanish Abengoa Group, which acquired all non-industrial arms of the company (Inovação Unicamp, 2010). Since 2006 Dedini has been negotiating with the Danish firm Novozymes about collaboration in the process, and in 2010 an agreement was reached (Inovação Unicamp, 2010). The prediction is that by 2012 the first plant of second-generation ethanol will be operating on a commercial scale. Novozymes are producers of enzymes, and with the new partner the idea is to use a combination of acid and enzymes in the process.

Dedini is also working with government agencies that have been supportive in developing new technology, such as FAPESP, which provided funds for setting up the Rapid Hydrolysis pilot plant (Inovação Unicamp, 2007). Together with FAPESP they are carrying out a number of new projects in the engineering development part of the company, and they are also collaborating on identification of strategic possibilities, a programme that in turn will generate spin-off projects. They are happy about tax reductions for innovation, which they are using, and they praise new funding forms from FAPESP, where applications for funds are joint calls between universities and firms, but they would like to see some changes in programmes. Their opinion is that it would be better if industry were to have a lead role and involve university resources in the projects, so that research projects better fit their strategic needs. Under the universities lead they perceive the projects as often being too slow and process too complicated for them (Inovação Unicamp, 2007).

Appendix 3: Copersucar

Copersucar (Cooperativa de Produtores de Cana-de-Açúcar, Açúcar e Alcool do Estado de São Paulo, or the Cooperative of the Producers of Sugarcane, Sugar and Alcohol of the State of São Paulo) was founded in 1959 as a cooperative to commercialise members' production. It is one of Brazil's largest sugar, ethanol and bio energy companies and is significant in world markets. It began with 10 mills in São Paulo and two regional cooperatives, Coopira and Coopereste. At present it has 39 member mills with centralised logistics, marketing and sales. The cooperative sets production quotas centrally for its members, with the ambition to adapt production and

amounts stored to optimise logistics and storage costs. This is done in order to even out market volatilities.

Copersucar pride themselves on having had a long-term focus on innovation and of participating in the modernisation of the sugarcane industry, supporting the professionalization of industry associations, and opening up new markets. They were initiators and important participants of the *Pró-Álcool* programme. They also participated in processes to remove government intervention by the IAA (Sugar and Ethanol Institute), which Copersucar found hampered innovation (Copersucar, 2010). To defend the liberalisation of the sugar market Copersucar has participated in the development of the Consecana system and worked towards the government to integrate ethanol as a component of the country's energy grid.

Copersucar also created a joint R&D unit that has become the most important R&D facility for the sugar and ethanol industry in Brazil, the Copersucar Technology Centre (CTC, Centro de Tecnologia Copersucar) (Ueki, 2007). In 1969 there were no Brazilian Sugarcane varieties; all were imported from India, Australia and the US. CTC hired consultants from South Africa and Australia in order to create their own varieties. In 1970 they had their first successful breeding, called SP7043 (T. Andrade, 2008). During the 1970s and 1980s they invested around 1% of their revenues in R&D (Martines-Filho, 2006). CTC used state-of-the-art laboratories, experimental farms and highly qualified professionals, to break through many technological barriers. CTC has interacted with domestic and foreign actors, initiated partnerships with universities and research institutions, for adaptation and creation of technology.

In 2004 the CTC changed status and opened up to all sugar firms, and currently it is jointly owned by 175 mills and representatives for 18 sugarcane growers associations, representing more than 2,000 sugarcane growers. It was also renamed the Centro de Tecnologia Canavieira or Sugarcane Technology Centre. The members pay a fee based on their size and have free access to the technology. Up to 2004 most of the cane varieties were optimised for São Paulo; now they develop more for other states. CTC carries out research. Today they are active in a number of areas, such as breeding programmes, agro-energy, transportation, industry processes, energy, software, safety management, soil laboratory and material labs. They get tasks from their owners, and when there is no supplier in an area they

develop new technology (T. Andrade, 2008). They also provide technical services, such as a benchmarking programme that aims at diffusing best practices among members. The programme keeps a database of the practices, and is available to improve members' performance, but also to serve as a basis for research at CTC (Ueki, 2007). Other interesting current projects include a project with the company New Holland to develop a device for compacting and baling straw left in the field. With mechanical harvesting being implemented in approximately 50% of mills in the State of São Paulo, and with the introduction of hydrolysis increasing the demand to take care of all biomass, there will be an increased interest in finding solutions to handle all the cane and straw (Inovação Unicamp, 2010).

They have developed new varieties, production techniques, animal feed from yeast, plastics, biological pest controls, biotech for sugar, ethanol, harvesting, transportation, vinasse, management and energy (T. Andrade, 2008). The varieties developed in the CTC's laboratories and fields today represent more than 40% of the sugarcane in the country. In partnership with FAPESP, the CTC financed the Sugarcane Genome Project (SUCEST), in which some 150 researchers from 16 institutions identified more than 40 thousand sugarcane genes. New technologies modernised cutting, loading and raw material transportation operations. They developed processes and equipment to improve efficiency, optimise the fermentation process and improve the quality of the sugar and ethanol produced (Ueki, 2007). CTC has worked with Dedini to develop the Dedini Rapid Hydrolysis and is also participating in the new project with Dedini and Novozymes.

CTC was entrusted by the Pró-Álcool programme in the end of the 1980s with searching for new alternatives to sugarcane use, and one of these projects was to make plastics from sugarcane, resulting in PHB (Molinari, 2006). CTC put together a team of 25 scientists, with partners from the Institute of Biomedical Sciences (ICB, Instituto de Ciências Biomédicas) of the University of São Paulo (Universidade de São Paulo, USP), who selected the bacterium and produced a transgenic variety that is more efficient in synthesising PHB. The Instituto de Pesquisas Tecnológicas (Institute for Technology Research, IPT) together with CTC elaborated technological solutions. When a feasible industrial process was established, CTC offered the technology to its members. The Balbo and Biagi groups were the partners that picked up on the idea and a pilot unit was set up in 1997. From that unit they learned that each final product needed alterations in the

plastic compositions, and they also found out that they lacked knowledge about market demands. In this process they established a partnership with the Department of Materials Engineering (Departamento de Engenharia de Materiais) of UFSCAR (Universidade Federal de São Carlos, or São Carlos Federal University), in which they could test different ways of producing finalised plastics. The outcome of the process has been five patents, three to IPT and two to CTC, which all are licensed to PHB Industrial S/A, which pays a royalty of 3% of sales. The knowledge that IPT and CTC got out of the project was later fed into other projects, and IPT, for example, received three more patents for polymers from other raw materials. Another important lesson was how to take knowledge into industrial production and make research interact on three levels: basic, technological and industrial.

Appendix 4: APLA

The favourable global trends provide a great opportunity for the sugar industry in Piracicaba, and in order to profit from it, the majority of the sugar industry stakeholders have come together in a cluster initiative, the Arranjo Produtivo Local do Álcool da Região do Piracicaba (APLA). The purpose is to address topics related to all of the sugar value chain and by collaborative efforts lower production costs, raise firms' competitiveness, to create global awareness about the sugar industry from Piracicaba, to develop the market through coordination of stakeholders and find complementary opportunities (Santos, 2006).

Most cluster initiatives in Brazil consist of micro firms with the same product. In contrast, APLA is a complete value network, of firms in all sizes. The APLA aims to coordinate stakeholders, and besides local firms there are 5 research and 19 policy or intermediary organisations participating (Santos, 2006; Amaral, 2008). APLA consists mainly of actors from Piracicaba, but there are also actors from Sertãozinho such as Sermatec (Castelar, 2008).

There have been different sources for the start of the APLA, but the most important has been Luciano Santos Tavares de Almeida (Stipp, 2006; T. Andrade, 2008), who at the time of the initiation was secretary at SEMIC (the department for trade and industry at Piracicaba municipality). In 2005 they were asked to arrange study visits for international investors, including ESALQ, CTC, Dedini, CSJ and Cosan. The firms could not handle this by

themselves and were interested in a coordinated effort for this. In 2006 there were around 6,000 visitors from 58 countries. At the same time Luis Forlan, Federal Minister of Industry, focused heavily on cluster initiatives and a dialogue with the industry. An initial vision was developed by Luciano Santos together with a consultant (Stipp) that had developed the Agenda 21 programme for Piracicaba. There was also input from actors such as CTC. To identify the relevant actors they went to CIESP to obtain a list of potential members (Stipp, 2006; Santos, 2006).

Another important source was SEBRAE (The Brazilian Support Service to Micro and Small Enterprises), which initiated a number of activities to support cluster initiative beginning in 2004 (Stipp, 2006). Early on in the process the idea was to develop from a basis of an informal network of metal-mechanical industries that supplied Dedini. Later on this was expanded to include all the stakeholders in the value chain. Much of SEBRAE's efforts were geared to the metal-mechanical industry and how to upgrade firms to be able to provide goods and services meeting international requirements, and also the demands of Dedini (Cavalieri, 2006 and 2008). SEBRAE has undertaken analysis of the needs of the firms and provided training for personnel. Vocational training will be carried out by SENAI. SEBRAE has also invited speakers to the APLA to talk about possibilities in collaboration, but has also financed university personnel and consultants to carry out analysis (de Freies, Burgos, Estacio, Cavalieri, 2006).

Three working groups on specific topics were created, each led by a different stakeholder. The agricultural issues group was run by ORPLANA (the small farmers' union), interested in new varieties; industry issues by SIMESPI (the syndicate for the metal-mechanical industry), interested in certification and new customers; and logistics and commercialisation by CIESP and sugar mills. The meetings included problem identification and vision creation. At the meetings external consultants provided examples of cluster work in other regions. The issues identified at the meetings, together with input from SEBRAE, led to the formulation of a strategy and a business plan (Amaral, 2006).

The APLA has a project manager who is in charge of daily operations. He interacts with three councils: i) the Superior Council, which consists mainly of public organisations and UNICA; ii) the Strategic Council, with three representatives each from industry, mills, agriculture, the technical council

from SEBRAE, and CIESP; and iii) the Technical Council, which consists of members of APLA, SEBRAE, ESALQ, and the prefecture (Castelar, 2008).

APLA has organised a number of activities:

- The ethanol tour, which has taken care of delegations from the EU, France, India, China, the US, Mauritania, the Czech Republic, Colombia, Sweden, etc. This was also the first activity of the APLA, before the more deliberative process (da Costa, 2006). It has become too popular, and has not always led to the desired deals, therefore the participating actors, CTC, EALQ, COSAN and Dedini have become much more restrictive (Izique, 2006).
- The development of a joint logotype and website to promote the cluster (Castelar, 2008)
- Arrangement of a conference, *Simpósio Internacional e Mostra de Tecnologia da Agroindústria Sucroálcooleira* (Simtec), with participation of 150 firms from Australia, South America, and United States with 22 thousand visitors (Santos, 2008).
- Together with APEX, a number of missions undertaken to other countries, such as South Africa, Colombia, Mexico, Central America and Europe (Castelar, 2008).
- A Certification of Alcohol programme, to show that the ethanol is produced in a socially responsible and sustainable way, to decrease international distrust of industry business practices. For example, when the Swedish agricultural minister visited Piracicaba, his first questions were whether there were problems with the rain forest, if they provide good-quality jobs and if there were problems with greenhouse gases (Amaral, 2008).
- The creation of an international standard of ethanol to make it a traded commodity, that is, not creating barriers to Brazilian producers, together with UNICA, Inmetro (the National Institute of Metrology, Standardisation and Industrial Quality) and US counterparts such as NIST (the National Institute of Standards and Technology) (Amaral, 2006).
- APLA and SEMIC, to develop an intermodal platform for transportation, including rivers, roads, pipeline, and railways (Calil, 2008; Mazzoldi, 2008).
- To address labour shortages, capacity-raising activities have been carried out through organisations, such as ETEC, SESI, SENAI and

SENAR (Santos, 2006). They have also prepared the establishment of a Technology College (FATEC – Faculdade de Tecnologia), with two-year programmes in five areas: logistics, marketing, industrial production, sugar alcohol production, human resource management (Santos, 2008).

- Information meetings for APLA members on potential financing for R&D projects, and information on new technologies and potential collaboration partners from R&D institutions.
- APLA has been a driving force behind the setting up of the Science Park for sugar industry technology firms that will open in 2008 (Izique, 2007). There are a number of firms that have decided to locate in the Science Park, such as Caterpillar, Novozymes, Shell, Total, Petrobras and Dedini. There will be colleges and high schools connected to the Science Park.

APLA has benefited from the strong international market, which makes it easier for firms to see benefits from and join collaborative process, as there are enough opportunities for everyone. Furthermore, APLA was initiated by a strong and well-accepted leader figure, Luciano Santos Almeida, who due to his personal background in industry and his position in the public sector, managed to engage both private and public interest in co-operating in the process (Stipp, 2006; T. Andrade, 2008).

Appendix 5: CSJ Metalúrgica

CSJ Metalúrgica is a manufacturer of specially designed equipment for sugar mills. It was founded in August 2004, as a co-operative by employees that took over it from the previous owner family, Santin. The family could not keep the firm together after an inheritance process resulting in financial difficulties. Before the takeover there were 900 employees; after restructuring 377 went on to the cooperative and 250 became joint owners. In 2008 there were 450 employees besides the owners. The cooperative is controlled by the members' assembly, and run by a president, vice president and fiscal administrative group. To help them to start up the co-operative the state bought the factory, through financing from BNDES. There is a ten-year payment plan to handle this credit (Sartori, 2008).

CSJ Metalúrgica mainly manufactures equipment for the sugar and alcohol industry, but some 20% of the production is for the petrochemical industry. The majority of their customers buy new parts for their plants. They do not sell many turn-key factories, but can take on the role of head contractor and then source from other suppliers. They work with partners that design and construct the mills, and sometimes they source smaller orders to other manufacturers. Important partners include: Fives Lille, which is a French technology firm; Bunge, a food factory manufacturer; Dedini, which supplies them with orders and who also helped them with equipment in the beginning; Conger, a partner that produces complementary parts. Many sugar factories have their own construction and design offices, which subcontract the manufacturing of equipment to CSJ. They have installed and sold products to Brazil, Paraguay, Venezuela, Bolivia, Dominican Republic, Colombia (Sartori, 2008).

Their main competitors in Piracicaba are Dedini with 3,000 employees, which has design, technology, construction and manufacturing; Sermatec with 2000 employees; NG with 1500; and Mause which has equipment and technology, with 500 employees (Sartori, 2008).

CSJ is an active member of the APLA, which they find greatly beneficial. They emphasise the missions that bring them into contact with new customers, but also strengthen the relation with other actors in Piracicaba. They have been to Mexico and Australia. Since the initiation of the APLA they feel that the relations between firms in Piracicaba have improved and that they help each other with handling orders (Sartori, 2008).

Their plans are to expand by buying a new and larger plant and to build large machinery in their plant and sub-contract smaller equipment to smaller firms. They want to hire more staff, but it is a challenge to find competent people, and there is therefore a circulation of personnel between the firms in Piracicaba. They intend to build competence in their personnel via the university and the colleges (Sartori, 2008). They have some collaboration with CTC and people from ESALQ in specific projects. They want to develop more proprietary technologies; they have some from the Santin times, such as boilers, but they want to develop for other areas as well (Correa, 2008).

Appendix 6: Usina Coruripe

One of the most productive mills in the region and also in the country's is the Coruripe in Alagoas, which has worked extensively with implementing new technology. This is sourced externally, developed in-house, in collaboration with the local university and from knowledge inputs gained from their membership in the CTC in Piracicaba. CTC also has a lab in the premises. Coruripe are constantly searching for new technology to use in their processes. In the last few years they have upgraded machinery, tractors, collector machinery, irrigation systems, begun using GPS systems, online meteorological stations, etc. They use around 20–25 different sugarcane varieties that are optimised for the different lands being used, and they test another 30,000 varieties every year.

Around Coruripe the land is dry for three months, which overcome with their irrigation system. The Coruripe plant is built around a river, and they have an advanced system holding 60 million litres of water in a dam, which they can then distribute in an advanced irrigation system which is 300 km long. To build the dam they obtained a loan of BRL 14 million from Banco do Nordeste (Almeida, 2007). The dam was built in cooperation with Caterpillar (located in Piracicaba), which tested new technologies for satellite control of mechanical equipment and built it in 5 months. The inspiration for the irrigation system came from the Dutch canal system. The irrigation is distributed over 3,600 ha of land, which is being further extended through a new pumping system to irrigate another 3,000 ha. The land that is closest to the river have a productivity of 120 tons/ha, whereas the total average is 90 tons/ha. Coruripe runs plants in many parts of the country, and the only difference in productivity, as they see it, comes from climate and terrain factors, not cultural or social factors (Almeida (2007).

Connected to the irrigation system are fertilisation stations that mix fertilisers into the water and also metal and gases to adapt the water's Ph levels to the appropriate ones for sugarcane, which is then distributed in canals to the fields. This system for mixing minerals and fertilisers is a proprietary one, which they have developed together with students from the University of Alagoas. They have also collaborated with students to develop a control system for the overall system. They use a Spanish system for watering the sugarcane, which they have adapted to their needs with the help of the local university. Connected to this system are also weather

stations, which connect to the watering system through a fibre-optic network which runs across the plantation; to fit this system to their needs they have used local students. After the water has been circulated inside their system, they send the water to be cleansed in a water cleaning system. For this system they have also used students to develop it.

They normally produce 50/50 of sugar and ethanol. Apart from this they generate electricity, and sell 32 MWh to the electricity grid. They are also successful in the market for emission rights. They have most of their activities in-house, but are members of CTC and Copersucar and have strong networks with RIDESA and universities for development of new technology. They also use external consultants sometimes. They do not produce all of their sugarcane in their own lands but buy some 25–30% of it externally. They also hire buses for transportation, 75% of the buses used.

An advanced computer system for administration of the business has been implemented. All cane cutters have their own magnetic cards that gives them access to the facilities, but it also connects to their accounts, and keeps track of the amount of cane they have cut each day. The card is also connected to their salaries and their health insurance and family benefits. Coruripe positions itself as an environmental and socially responsible firm, and in this process they have undergone a number of certification programmes (e.g. ISO 1200) and started an institute for preservation and reintroduction of rain forests and also started an institute to develop business ideas and labour opportunities for small-scale firms making handicrafts and nutritious products from honey and sugar residuals.

In Coruripe 96% of the land is flat; within a not too distant future they will mechanise harvesting to the tune of 100%. The estimations are that one piece of machinery will replace 15 people and that this can be managed by the 2,200 permanent employees (Almeida, 2007), but the 4,000 seasonal workers will lose their jobs. Currently they have not mechanised as an act of social responsibility. However, with the laws prohibiting the burning of sugarcane and due to competitive pressures, Coruripe will begin mechanisation in the not too distant future.

Appendix 7: UBPC

This UBPC is a cooperative of 167 workers and according to the respondents the size of personnel was sufficient for their operations. In a UBPC they own everything but the land, which is the state's. The manager of the UBPC, Lazaro Leon Gimenez, came from a CPA in 2003, and sees little differences between the cooperatives, except that the CPA owns its lands and that the UBPC rents its land from the state (Gimenez, 2008).

In the UBPC it is the co-operatives assembly that decides everything. They set salaries and the connection to work unit measurements. The assembly comprises all the members of the UBPC, only the workers and not their families. One has to be over 17 to be a member. They can accept new members; first they are tested and then need to be approved by the assembly. There are no ownership rights that can be sold.

Many of the UBPCs have had grave financial problems; the situation is the same for this co-operative. They have received support for workers' clothing and other material, and they receive government support if they are not rentable. Firms in Cuba cannot go bankrupt. They receive bank loans and can renegotiate the debt. They have a debt of over 1,000,000 pesos that they hope to be able to repay in 10 years. The debt is a result of the Special Period. They are otherwise supposed to be able to handle themselves (Gimenez, 2008).

The UBPC has a social objective, and an assignment to solve. They need to produce what society needs and what is decided by the ministry and the central. They cannot decide their production mix by themselves. Their assignment is to produce sugarcane, meat and milk. They have a large debt and the government's influence is very strong. They follow the discussions of Fidel closely and agree with him that sugarcane is for food and should not be used as fuel, as it is an absurdity of the First World (Gimenez, 2008).

They have 1,272 hectares of land that they use primarily for sugarcane, 1,118 ha, but also for rice and meat, and then there are 33 ha of forest. In the harvest season (November to April) they cut 21,800 tons of cane, for this purpose they rent the services of the Cameco unit from Hector Molina. The cane that they harvest is approximately 22–23 months old. The ambition is to have a yield of 31 to 34 tons/ha. They need to surpass 33 tons to break even. This is not something they have done in the last few years; in

2007 they reached 29 tons per ha. In the 1980s they often reached 60 tons per hectare. All of their land is irrigated and they are experimenting with varieties to adapt optimal varieties according to humidity of the land. All of the terrain is mapped to keep track of the specificities of the land (Gimenez, 2008).

Acopio, the purchasing board, is part of the refinery. They are the ones that decide prices, which in 2008 were around 50.9–52 National Pesos per ton, depending on the sugar content (Leon and H. Torres, 2008). The salaries of the employees are the basic salary, 500 pesos per month, in addition to which they get 13 pesos per basic unit of work they carry out, e.g. cutting 250 arrobas or roughly 3 tons of sugarcane is one unit (Gimenez, 2008).

There is also an incentives programme that provides workers with 30 cents convertible/tons extra, on condition that: i) the UBPC is rentable, ii) they produce over 33 tons/ha, and iii) they replant everything they harvest. This will give them 30% extra funds, which is divided among all the people of the cooperative. There is also a disincentives programme to make them supply the refinery with statistics and to prevent cane burning; if they do that, they will not receive any bonuses. Cane is still burned in some places, even though it is prohibited.

Appendix 8: The Sugar Refinery Hector Molina

The origins of the refinery go back to the Eugena La Teresa, which was built in 1850; in 1930 its name was changed to Gomez Mena and in 1960 to Hector Molina (who was a revolutionary noble). In 1997 the refinery was reconstructed and five former refineries merged into one; among the ones merged with Hector Molina were the refineries of Lincoln and Amistad.

Hector Molina organises not only a sugar refinery and an alcohol distillery, but also agriculture production, independent units of mechanised sugarcane harvesters (Cameco), technical services, units for transportation and construction, and the purchasing board (the Acopio).

During the harvest, they receive and process 6,900 tons of cane per day and produce 15,000 litres of 93% alcohol per day. Some 10–20% of their cane is cut by hand the rest by harvesters. They use both Cuban KTPs and American CAMECOs.

CAMECO is a unit within the refinery that has mechanised harvesters (MINAZ is the owner of the refinery). They work three machines together, and the unit sells its services to other units, such as the UBPCs and CPAs. They use CAMECO machines from Louisiana, bought from Panama. They cut 250 tons in 12 hours. One operator per machine works in shifts of 12 hours. They assist with transportation of cane if it is not carried on the railway network (run on petrol, steam trains, and charcoal) that surround the refinery. For that purpose they use lorries from TransMinaz, the MINAZ unit for transportation.

They organise 36 production units in the surrounding region, 7 state farms which send their cane to the refinery, and 29 non-state farms, of which 11 are UBPCs, 10 CPAs, and 8 CCS. The latter sell their material to the refinery according to contracts. However, these units cannot decide to change their production if the refinery objects to it. The management of the refinery has the final word in discussions about production with the surrounding production units.

Around the sugar refinery is a municipality where the employees live. The number of inhabitants is 10.000, of whom 1,500 work in the refinery proper. They do not have any seasonal workers, and during harvest times they work in three shifts, 7–15, 15–23, 23–7.

This refinery has grown since the crisis so they have not noticed the downsizing elsewhere. Many of the people who had to leave the industry due to the downsizing have been advised to participate in educational programmes, e.g. in SUMs. There is a SUM close to the refinery; among other subjects they teach agronomy and accounting. The teachers come from the University of Havana and some come from the refinery's employees.

The refinery works together with ICIDCA, the other institutes and the University of Havana; among other things they receive students from the university's R&D unit for agriculture. There is also a polytechnic school close to the refinery (Técnico Azúcar), which is part of the educational ministry; here too there are teachers from the refinery who sometimes help out as teachers. It is a high school with both theoretic and practical (such as cutting cane) elements.

When it comes to diversification, they decide together with the local authorities and with the ministry. Since the crisis they have also been assigned to arrange provision of food for the local region. In 2003 they abandoned non-productive land, and cut down sugar production, at the same time as the concentration of the five refineries into one. The refinery produces 1 million litres of milk, 50 tons of derivatives (yeast and animal feed) and meat, pig and beef, besides 11 MWh of electricity . They produce 31,000 m³ of alcohol (the estimate in 2006 was 50,000; Nova, 2006), in three different forms: i) Hidratado 95% (for pharmaceutical purposes), ii) Fino 96% (some of which is used for rum; so far it is not exported or bottled, but they are experimenting with producing more advanced versions which are stored in barrels), and iii) Técnico B, 93% technical alcohol which is used for heating homes and distributed to other distilleries who refine it. They do not have equipment for dehydration, which prevents them from producing ethanol for biofuels. The refinery is constantly looking for new products and derivatives and has experimented with mixing of 5% ethanol in petrol. They have their own organisation for transportation, with trains and buses that could benefit from this (Martinez and Caballero, 2008).