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Chinese Innovation

An Empirical Study of Chinese Innovation Creation

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Abstract

China's economy has for more than 30 years experienced constant rapid growth. The growth miracle has largely been attributed to export, but in recent years the growth strategy has been changed. The new ambition is to go from "Made in China" to "Innovated in China". This study investigates the input channels that create innovation in China, and panel data analysis is used to analyse which factors create innovation.
The result shows a positive significant relationship between innovation and research and development expenditures. Also foreign direct investments have a positive relationship with innovation. The study also contributes with a result that questions the optimal way of measuring innovation.

Key words: China, Innovation, Patent, Panel data

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1 Introduction

1.1 Introductory statement

This thesis is about Chinese innovation policy and what creates innovation in China. It is a topic of great importance that has gained more attention since China's rapid economic development. With this thesis I want to investigate which factors create innovation in China.

1.2 Background and Motivation

In the year 1978, Deng Xiaoping introduced the economic reforms that would come to reshape China dramatically, beginning a new era for Chinese economy and society. The reforms increased Chinese competiveness and trade performance. After more than 30 years of constant rapid growth since 1978, the rest of the world started to wonder if the Chinese growth miracle had an end. The rise of the Chinese economy has been largely attributed to the export of low quality goods and the assembly of other countries' inventions. This is not always a good deal; for example, a Chinese DVD exporter receives a one-dollar profit for the export of a DVD player sold for 34 dollars in a store - the foreign patent owner receives approximately 20 dollars per unit. China has been satisfied with this deal for the last 30 years, but now the strategy has changed - they want to go from made in China to innovated in China. As China's president Hu Jintao puts it, "Independent innovation is the core of national competiveness". But how is China going to create innovation? (The economist, 2012)

Empirical studies and theories emphasise foreign direct investments (FDI), industrial clusters and R&D expenditures as important factors that affect innovation. All of these factors are represented in China's latest fifteen-year plan for science and technology development presented in 2006. These three factors are believed by the Chinese government to be keys to Chinese innovation creation. But do they live up to the expectations? This study will investigate the impact of these three factors on Chinese innovation.

1.3 Purpose and Problem

Economists have primarily focused on the amount of resources allocated to innovation and the resulting economic output. It has also been common to treat innovation as an existing, exogenous variable, “manna from heaven”. (Jones, 2002: 36) In my essay I will focus on the creation of innovation, instead of the economic gains from innovation. If you cannot understand the source of innovation it will be hard to actively support its development. There is a great number of theories that try to explain why innovation occurs from a wide range of economic perspectives. In chapter three I will discuss the main theories and ideas used in this essay.

There are discussions about Chinese innovation and innovation regions, but there are few studies on what actually increases innovation in China. By examining Chinese regional innovation, my aim is to determine if the strategies presented in China’s fifteen-year innovation program are a winning concept. In the fifteen-year innovation plan three main sources are discussed to increase innovation: Research and development expenditures (R&D expenditures), industrial clusters and foreign direct investments. I will attempt to answer the question:

How do foreign direct investments, industrials cluster and R&D expenditures influence Chinese innovation?

In this study China will be divided in to its 31 main regions. By analysing the three factors mentioned in the fifteen-year plan, the aim is to examine if these factors create innovation in China. I hope that by examining the regions and finding factors that correlate with innovation it will be possible to find the main reasons behind a successful Chinese innovation climate. Innovation is a wide concept and there are many different ways to quantify it. This is an interesting aspect of innovation, but it makes it tricky to measure. Therefore, in this study two different measurements will be applied. This is also done to see if there are any major changes in the result depending on how innovation is measured.

1.3 Disposition of the Study

In chapter two, an overview of Chinese innovation policies will be presented. In chapter three the theoretical framework will be discussed. In chapter four the method and model used will be specified, and in chapter five the result will be analysed.

2 Chinese Innovation Policy

In 2006, the state council of China presented a fifteen-year program to improve China´s scientific and technological development. The program is a result of China's ambition to become a leading, knowledge-based economy. In the program there are specific targets for China, which are supposed to be accomplished by 2020. The main goals are to reduce China's dependence on foreign research and development, as well making the Chinese business sector more interactive with the innovation process. The Chinese government is expecting that the plan will make a major difference for China's future innovation capability and economic growth (Schwaag-Serger, Breidne, 2007:2-5). But how is it possible that a country that 30 years ago was suffering from starvation and economic recession now aims to become one of the world's leading, technology-based economies?

To fully understand this chapter it is of importance to define innovation policy. I define it in line with European commission's definition: "We define innovation policy as a set of policy actions to raise the quantity and efficiency of innovative activities, whereby "innovative activities" refers to the creation, adaptation and adoption of new or improved products, processes, or services." (European Commisson, 2000:4)

2.1 Chinese Innovation in the Past and Future

2.1.1 Innovation in the "new" China (1949-1978)

In the beginning of the communist party's rule in 1949, science and technology (S&T) was not paid much attention, and the potential for economic growth through S&T was generally ignored. Economic goals were achieved through strictly planned models directed by the founding father of china, Mao Zedong. The strategies turned out to be poor with regard to technological and economic development. In this time China followed a centrally planned, Soviet Union model for research and development, constructed with a strict hierarchy and bureaucracy from top to bottom (Swanson, 2008:1-8).

China managed to develop nuclear weapons and other military equipment with support from the Soviet Union, but the centrally planned system seriously damaged China's technological and economic development in other fields. The next obstacle on China's way to become a more knowledge-based economy was during the Culture Revolution (1966-1976). After years of starvation and political turmoil, Chinas prime minister, Zhou Enlai (1898-1978), in 1964 launched a plan for the modernization of agriculture, industry, defence and science and technology. At the time, Chinese universities blossomed and the number of students peaked. However, the reforms never took place, as Mao's Red Guards started a new campaign to promote their ideology. During this time many universities closed down, students and personnel were sent to the countryside to do manual labour, and a generation of knowledge was lost. At Mao Zedong's death in 1976, the revival of Chinese science and technology began, and the mark of a new era of Chinese innovation took place when Deng Xiaoping opened up the Chinese economy (Serger, Schwaager, Breidne 2008:138-139).

2.1.2 China's post-1978 (1978-2005)

After 1978 China's innovation policies started to get a more political focus, and the famous Chinese leader Deng Xiaoping remarked that S&T is the primary productive force and that intellectuals are part of the working class. The ideological framework was set, and S&T strategies were ready to be made. After the first implementation of China's 'open door policy', allowing for an increased inflow of foreign investment and trade, five major national S&T conferences took place. During these conferences main strategies for S&T and innovation policies were developed, and previous policies were evaluated. In the following three sections, important Chinese innovation policies will be presented, divided into three time periods. (Liu, et al. 2011:919-921)

In the first period (1980-1984) 17 innovation policies were launched with a focus on reforming China's S&T system in the aftermath of the destructive culture revolution (Liu, et al. 2011:920). 'Special economic zones' were established, with the aim of increasing trade and also increasing the pace of technological transfer between FDI and China. Many new national S&T programs were launched, creating a platform for future innovation and development. (Branstetter, Lardy 2006:10-11).

In the second period, (1985-1994) 76 innovation policies were developed. One of the most important policies was to again reconstruct China's S&T system. The reason was to keep it up to date with the on-going economic development in China and to form a more conducive environment for S&T development. The reforms were implemented in 1985-1988 and had direct effects with the development of high-tech concentration areas with linkage to universities and research institutes. During this period a lot of laws were implemented to protect the market and enterprises from market failure. The Patent law was adopted as well as a number of laws regarding anti-unfair competition (Liu, et al. 2011:922-923)

In the third period (1995-2005) the number of innovation polices dramatically increased and 287 new policies were implemented, compared to the 76 in the time period before. In this third generation of reform-oriented leadership the "revitalizing the nation through science and education"-strategy took place in 1995. According to Hutschenreiter and Zhang (2007) the adaptation of this strategy could be seen as a sign of China's recognition of the weaknesses of relying on foreign technology, and the insight that future competiveness is set by a country's technological capability (Hutschenreiter, Zhang. 2007:249). Policies from the first S&T conference in the early 21st century began to shift the focus from innovation created by government research institutes to innovation created by privately owned S&T enterprises.

To summarize the development of Chinese innovation policy between 1978-2005, the number of innovation polices have steadily increased and the goals have varied. In the first two periods the focus was to rebuild S&T institutions and creating a reliable system with a more efficient innovation climate. In the later period, the aim has been to develop S&T/innovation to compete with the large global actors.

2.1.3 New Policy Initiative (2006-2020)

In the introduction of this chapter I refer to China's fifteen-year program for science and technology. This is an ambitious program aiming to strengthen the Chinese innovation force in to the future. Notice that I use the word "program" instead of "plan". The reason for this is that at the announcement in 2006 of this long-term strategy, the State Council changed its rhetoric from that of previous years. Instead of using the word *jihua* (plan) they used *guihua* (program). This was an interesting change, distancing the strategy from the traditional "plan economy" by using the word "program". This could be seen as a hint of the development for the upcoming years (Serger, Schwaager, Breidne 2008:137).
At the National conference on Science and Technology in 2006 Wen Jiaobao, the current premier of China summarized the programs ultimate goals:

- To develop technologies related to environmental protection
- To Master core technologies in IT and production technology
- To catch up with the most advanced nation in areas within biotech
- To increase development in space and aviation technology
- To strengthen both basic and strategic research

(Serger, Schwaager, Breidne 2008:145).

There are a handful of policies that have been or will be implemented to achieve the goals presented in the program. The three methods that will be the focus of this study are increase in R&D expenditures, science and technology parks and FDI.

2.2 Chinese Innovation Institutions

In the following section we will briefly look in to three of the main institutions that are of great importance in the complex network of Chinese innovation policy, showed in fig.1 (see appendix).

The Chinese bureaucratic system is highly efficient in implementing economic policies and the sophisticated framework is one of the reasons behind China's economic success story. The same system also deals with policies related to science and technology (Lieberthal, Oksenberg,1988:644-650).

The highest innovation coordination body in China is the State Steering Committee of S&T and Education founded in 1998. The committee is a decision-maker for national education and S&T strategy and coordinate innovation policy. It is also the developer of the fifteen-year National science and Technology Development program mention in the begging of this chapter (Huang et al. 2004:369-370).

The Ministry of Science and Technology (MOST) is another important actor in Chinas innovation structure. Its main task is to implement and fund R&D programs, support small and medium enterprises (SME), innovation activity, and to encourage the construction of Science parks throughout China (Huang et al. 2004:369).

The third key player in the innovation policy system is The Chinese Academy of Science (CAS), an institution founded in 1949. It is a national think-tank with multiple functions in research, technological development, hi-tech training and transfer (Liu, Simon, Sun, Cao 2011). Over the years this institution has been reformed and reconstructed several times, today it includes 100 laboratories and national engineering centres and it employs over 50,000 people. CAS is the brain behind hundreds of Chinese innovation success stories, the second largest computer manufacturer in the world, Lenovo, being one of them (CAS, 2012:Introduction).

These three institutions create the backbone of Chinese innovation policy and they interact with a wide range of other administration organs. Altogether they make a complex network of institutions (see appendix) aiming to develop and increase Chinese innovation.

3 Theory

In this chapter theories and previous studies regarding innovation will be presented. This is done in order to understand the mechanism that creates innovation in China.

3.1 Different Innovation Perspectives

Many economic theories try to explain why innovation occurs. I will in this chapter review relevant theories and empirical studies that discuss innovation from different economic perspectives. I will pay extra attention to the three prime theories of R&D investments, industrial clusters and foreign direct investments impact on innovation.

3.1.1 Organizational Innovation

In the field of organizational economics there has been a long tradition of investigating the relationships between firm structure, economic performance and innovation. The relationship is dynamic and multileveled, which generates a diverse field of study (Lam, 2005:138). The field with focus on innovation can roughly be divided in to three different research areas:

- The relationship between organizational structural forms and innovativeness.
- Innovation as a process of organizational learning and knowledge creation.
- Organizational capacity for change and adaption.

Lam (2005) emphasizes that these fields interact with and overlap each other. One problem with this theory is that the term, "Organizational innovation" has many different definitions. As a result, there is no generally accepted definition of this term, and it can mean different things in different contexts. Every theory needs to be carefully investigated to ensure that it has been correctly understood. Two popular organizational economic theories with ties to innovation will now be presented (Lam, 2005:115-118).

Lawrence and Lorsch (1967) developed the theory "conceptualization of organizational design problems as differentiation and integration". This theory argues that business enterprises in developed countries have to accomplish a higher degree of organizational integration to be able to sustain competitive advantages. Organizational integration is defined as the integration in the company, the connection between shop-floor workers up to the company board. According to the theory, a superior organizational integration strategy enables the company to coordinate its resources and create a more innovative climate (Lam, 2005:121). But how is a company supposed to be organized in order to get this innovative climate?

The idea that there is “one best way to organize” was introduced by Max Weber in the 1950s and has been widely discussed since then in economic literature. The theory claims that there is one best way to the organize leadership, personnel and company structure depending on company goals. However, this theory is challenged by the contingency theory, claiming that the best structure is the one that best fits a given operating contingency. Contingency theorists would claim that there is no given innovation strategy for all companies, and it is dependent upon the firm and the environment it is integrated in (Pugh, et al. 1969:111).

By conclusion, organizational innovation focuses on the structure of companies in order to create innovation. In the field there are different opinions on how innovation is created, but all of the theories focus on the importance firms’ decisions and structures in creating a positive innovation environment.

3.1.2 National System of Innovation

Christopher Freeman first introduced the expression “national system of innovation” (NSI) in 1987, since then it has become a popular innovation approach. Freeman defines it as “The network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies.” (Freeman 1987:1). The NSI approach has rapidly gained popularity in academic circles, but also by national governments and international organizations. NSI attraction from policy makers comes from the efficient framework to understand and be able to support technological development and innovation (Edquist, 2005:184).

In the NSI approach, focus is on organizations and institutions and the flow between them. The technology and knowledge flow between actors is a key to innovation according to the NSI approach. An example could be firms providing trainee spots for university students in order to integrate them in to the market. This could be a part of a successful NSI model.

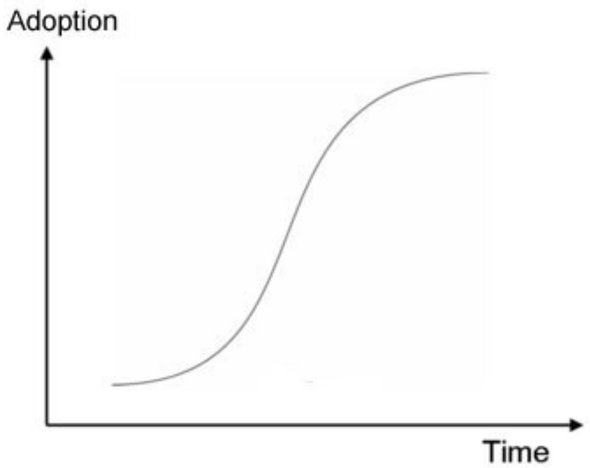
Positive aspects are that the NSI approach places innovation and learning in focus, looks to the process of innovation and uses the scope of many social science disciplines (Edquist, 2005:184-186). Edquist (2005) points out that the main weakness in the research area is conceptual issues. What exactly is a national system of innovation? What is the correct definition of institution and organization? These weaknesses make NSI an “approach”, rather then a formal theory in the sense of not specifying casual relations among the variables. Still, the NSI approach remains a popular framework for analysing innovation (Edquist, 2005: 201-203).

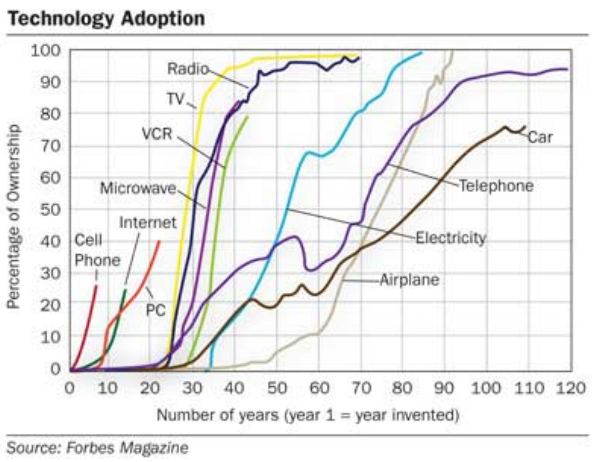
3.1.3 Diffusion of Innovation

Diffusion of innovation is a theory that seeks to explain how, why and at what pace innovation spreads through society. Without innovation diffusion, innovation would not be able to spread and would have little impact on the economy. Why is innovation diffusion sometimes slow? And how come the diffusion pace differs among countries? Questions like these were investigated by the sociologist Evert Rogers in his book "Diffusion of Innovation" (1962). Rogers developed a framework with factors that influence the adopter's decision of rejecting or accepting an innovation:

- Relative advantage of the innovation
- The innovations compatibility (with the adaptors way of doing things)
- Complexity of the innovation
- Trialability, the effort with which the innovation can be tested
- Observability, the effort with which the innovation can be observed
  (Hall, 2005:461)

According to Hall (2005) many of these factors have been empirically observed in analyses of specific innovation diffusions. They also create a helpful framework for the field of marketing and evaluating the next generation of innovation (Lowrey,1991:644).
Diffusion theorists are not only interested in the actual implementation of an innovation, but the whole cycle of the adaption. The S-curve is a well-known phenomenon, and a popular analytic tool in the field of diffusion of innovation (Hall, 2005:467)





(1) In the early stage the adaption is slow. (2) Then it accelerates as the innovation gains interested by the target group. (3) The target group is saturated and the adaption pace slows down.

3.2 R&D investments and innovation

In this part I will examine economic theories that discuss research and development (R&D) expenditures relation to innovation. Traditionally an increase in R&D expenditure has been seen as a key strategy to secure technological progress and innovation (Trajtenberg, 1990). R&D expenditure is also a common way to measure innovation, although it has been criticized for measuring the input and not the actual innovation outcome (Smith, 2005:152).

R&D activities in firms have become an institutionalized and predictable source of inventions, improvements and innovations. But the actual process of innovation is complex, involving many steps and difficulties. As a result, it is hard for firms to predict the next innovation and what it is going to be like, and many years of research do not necessarily have to lead to an innovation. According to Griliches (1990) a large proportion of corporate R&D spending is going toward unsuccessful projects. On the other hand, some of the R&D investments lead to successful projects and perhaps innovations, and without the investment there would not be a chance of a positive turnout. R&D expenditures can be funded by private or public resources, and which project that gets support is dependent on the investor. (Grilliches, 1990:1610)

Government-funded programs have many times been of major importance in innovation creation. Information and technology funded programs in the USA adapted to the military industry created early prototypes of computers, semiconductors and the Internet. From Japan and France government R&D investments successfully supported the development of high-speed trains (Pavitt, 2005:98). Government investment decisions are often pressured by lobbing-groups working for companies in specific industries. This process can lead to bad decisions and missed innovation opportunities. A positive aspect of government investments is that they can support innovation development in risky industries, where private actors do not want to invest. It can be argued that diversity and experimentation with government-funded projects creates a dynamic innovation climate (Pavitt, 2005: 98).

There are empirical studies that link R&D investments with innovation. Zachariadis (2003) studied U.S manufacturing between 1963-1988 and his result showed an empirical positive impact on R&D intensity and innovation. In other words, an increase in R&D expenditures result in increased innovation. A recent study by Pahlavani et. al (2011) comes to the same conclusion and find a significant relationship between R&D intensity and innovation performance in OECD and non OECD countries. Pavitt (1983) presented an important result; that factors leading to successful innovation differ widely across sectors and industries. This implies that an increase in R&D expenditures only benefits some sectors and industries, and does not necessarily lead to innovation in general. The medical industry may be dependent on expensive equipment in order to create innovations, but a social science researcher only needs pen and paper to come up with an innovative company structure. Not all research branches have the same needs. *Hypothesis 1: R&D expenditure has a positive relationship with innovation*

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3.3 Externalities of Foreign Direct Investments

In this part a review of theories and empirical studies regarding externalities from FDI technology will be presented.

British economist A.C Pigou developed the theory of externalities in the early 20th century. The theory examines cost or benefits for one party due to the activity of another party. This phenomenon has been observed in all kinds of economic activity, but in this part the focus will be on technology externalities from foreign direct investments that can lead to innovation (Chander, 2006: 111). The definition of foreign direct investment various across countries, but generally it is regarded as an investment of 5-15% or more in a company situated outside the home country of the investor.

When multinational corporations establish on a new market they tend to bring technology and managerial practice superior to the local companies. Otherwise it would be hard to compete with the local firms having an advantage of being more familiar to the market. (Blomstrom, Sjöholm, 1999:8-10) There are several theories discussing the process when technology spillovers occur between foreign and local firms. Three important once according to Greenaway et al (2002) are:

(1) *Knowledge transmission through the supply chain.* Foreign firms transferring know-how to their subcontractors in the host country, during trade process.

(2) *Skilled labour change employer*. The employee transfers foreign knowledge to the new domestic firm.

(3) *Through the demonstration effects*. Domestic firms imitate and get inspired by the foreign firm.

The identification of these transmission channels gives a clue to the relationship between FDI and technology spill over effects. The presence of foreign enterprises in host countries is treated with different levels of enthusiasm depending upon the host country. In the US, there have been some concerns with foreign companies establishing enterprises in the US market, and potentially eroding the national knowledge base. In other countries foreign direct investments is looked upon very differently, and seen as an opportunity for upgrading national technology systems and innovation capacity.

Theoretical literature regarding FDI was first developed in the 1960s. Many of these studies focused on the costs and benefits of FDI to a host country. MacDougall (1960) was one of the first to systematically include external effects as a possible consequence of FDI (Blomstrom, Kokko, 1998:8-9). These first studies were the start for the research field with focus on links between FDI, externalities and innovation.

There are nowadays many studies analysing FDI impact on the domestic market. According to Narula and Zanfei (2005:338) there are many empirical studies proving the existence of FDI spill over effects in emerging economics, but in developing countries there are less proof of a spill over effect. This indicates again a difference between countries in the adaption of innovation capability.

In the next section some important studies related to FDI spillovers will be presented. Some supporting the theoretical approach of a positive relationship between FDI and technology spill overs.

Rhee and Belot (1990) found empirical evidence on foreign firms being responsible of starting up the domestic textile manufacture in Mauritius and Bangladesh. Observing knowledge transfer from the foreign to the local companies. As discussed earlier there are studies going in the opposite direction, emphasises that FDI generates small or no significant spill over effects at all.

According to Fu in his OECD report (2008) there is a significantly positive externality from FDI to overall regional domestic innovation capability. The strength of the FDI effect on innovation in the host country is dependent on the absorption capability of the local firms (Fu, 2008:22).

Hypothesis 2: Foreign direct investments generates spill over effects that have a positive effect on Chinese innovation.

3.4 Sectorial industry cluster

Agglomeration and industrial clusters were for a long time ignored in economic literature, but are today increasingly accepted in economic theories. Many theories and empirical studies have investigated the relationship between spatial clusters and innovation. In this section essential parts of the research will be presented.

Industry clusters were first introduced by Michael Porter (1990) and is defined as: "…a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementaries…" (Porter, 1998:119). Porter has since then developed many theories regarding industry clusters and innovation. Porter notes the paradox that even though we live in a globalized world where technology and communication improve every day, industrial cluster concentration is still relevant. Industry clusters generate a competitive advantage and the informal channels of communication as face-to-face interaction is important and creates incentives for innovation creation (Porter, 2000:19).

Industrial clusters generate a close linkage, not only between employees in similar industries but also to buyers, suppliers and other institutions. This dynamic within industrial clusters increases the efficiency and innovation rate (Porter, 2000:19). Firms in industrial clusters more rapidly comprehend what the market wants than isolated firms. The reason why is once again, concentration. In an area with many major companies there is a lot of knowledge about the market. This knowledge spreads across the industrial cluster, and buyer-trends get picked up more easily. This market knowledge generates an innovation opportunity, which is difficult to match for isolated firms. This trend can be seen in Silicon Valley and Texas-based computer companies where new market trends quickly and effectively get picked up (Porter, 2000:23).

Peer pressure and constant comparison between firms in similar industries can increase innovation performance. There are also several advantages with industrial clusters that indirectly enhance innovation. For example they enable easy arrangement of joint marketing and trade fairs. Clusters attract institutions and local training programs, but also foreign scientists impressed by the cluster's reputation (Porter, 2000:20-23).

However, Porter also observes weaknesses that may occur when a firm is participating in an industry cluster. When clusters start to share the same value a sort of group thinking may suppress new ideas and innovation development. Another negative aspect is that radical innovations, an invention completely new to the market, may not be easy to develop in industrial clusters. This is because it can be hard to cut established connection and routines within the cluster to try something new (Porter, 2000:24).

One theory that has a similar research area as Michael Porter's is the New Economic Geography (NEG) approach. The theory has gained a lot of attention in recent years, partly because Paul Krugman was awarded the Nobel Prize in 2008 for his contribution to the field. Among other things NEG discusses innovation in a geographical context. Its main approach is that firms become concentrated in industry clusters because it increases their returns to scale. This increase is the result of several underlying factors. Two important factors are positive externalities within the cluster, and reduced transportation costs. Transportation costs are reduced since key suppliers are often located close to industrial clusters (Venables, 2005:3-5).

There have been many empirical studies related to cluster and innovation and some important once will be presented in order to understand the research field. An early empirical study of clusters' impact on innovation was conducted by Angels (1991). The study emphasizes clusters' role of being a dynamic area with rapid circulation of knowledge, a beneficial climate for innovation creation.

Steinle and Schiele (2008) summarize an American and a British study that links higher employee density with increased productivity from the employee. Baptista and Swann (1998) show in their study that firms in clusters are more likely to be innovative.

Malmberg and Power (2005) discuss different hypotheses to find out ways clusters can affect knowledge creation. They summarize previous literature in the field and come to the conclusion that informal knowledge exchange happens in cluster region, a factor that strengthens innovation force. This is related to Asheim and Gertlers (2005:291) idea that innovation activity is not randomly distributed across countries, but that knowledge-intensive economic activity is more geographically clustered. According to the research discussed in this chapter there is a positive relationship between industry cluster and innovation factors.

Although there are economists that emphasize clusters' role of being overrated as an innovative creative environment.

Hypothesis 3: Sectorial industry cluster has a positive influence on innovation.

4 Method

In this chapter the method used to investigate the relationship between FDI, industrial clusters and R&D expenditures will be presented. Also, the dataset and the variables used in the empirical study will be discussed. In the last section of the chapter the econometric specification for this study will be presented.

4.1 Choice of method

I have chosen to use a panel data analysis approach, since this is the most suitable method to analyse the dataset and answer the questions in this study. Cross sectional and time series analysis are two other popular research methods used widely in quantitative studies. Panel data analysis possesses advantage over both of these methods, as it enables cross sectional and time series analysis at the same time. This creates a more dynamic model, which allows for the empirical study of the behaviour of small groups (Wooldridge, 2011:215-216). Although, it should be noted that cross sectional and time series analysis are not always a weaker alternative to panel data, and the choice should depend upon the object and data available in the particular study.

Panel data-sets often contain a very large number of observations, which gives a rich content to analyse. Suppose a cross-sectional method was to be used with ten individuals and five variables - this gives us 50 observations. If the same study would be replicated but over a ten-year period, our material would instead contain 500 observations, and a more extensive study could be made (Dougherty, 2011:409). A greater number of observations means a better statistical result.

The two primary approaches for fitting models to panel data are fixed effect regressions and random effect regressions. There is also a number of versions of both approaches that need to be selected to fit the purpose of the model. The most common one and the one used in this essay is the within-groups regression. It explains the variations around the mean value in the dependent variable in terms of the variation of the means in the independent variables, this is referred to as the ‘within effect’ (Dougherty, 2011:409-412). Fixed effect is applied to the regression since the data used in this study is a systematic sample of a given population, according to Dougherty’s (2011) decision rules.

A weakness of the within-group regression model is that the intercept and any variable that remains constant during the time period will be eliminated. The reason is, as mentioned before, that it measures the within effect, and with no change in the value the within effect will be zero (Dougherty, 2011:412). Fixed effect regression analysis has its weaknesses, but in general it is the strongest approach for this study.

4.2 Data

The data used in this thesis is collected from China Statistical Yearbooks, the official statistical institution of China. The yearbooks are divided into different parts and the ones used are: China Statistical Yearbook, China Statistical Yearbook of Science and Technology and China Torch Project Statistical Yearbook. The yearbooks have been provided through the online sources China Statistical Data Service and The Asia Portal. (NIAS)

The data has been collected between 2005 and 2009. More recent data was not available for all the variables used. This is not a problem, as the goal of this study is to analyse Chinese innovation creation in recent years, and this will still be possible.

The dataset is divided in to 31 Chinese regions according to the Chinese Statistical Yearbooks distribution, excluding Taiwan, Hong Kong and Macau. Eleven variables have been included in the study and they are divided in to dependent, independent and control variables. The data is sorted as a balanced panel dataset with repeated observation of the variables for all of the regions during the time period between 2005 and 2009. All the variables have also been divided by the population in the specific region in order for the regression to be more accurate.

Chinese statistic reports have been criticised by various sources for being unreliable, and they have sometimes also been called “man-made” (Reuter, 2010). This is not a new discussion; throughout the twentieth century there have been availability issues and doubtful Chinese statistical reports. There has also been a problem with purposeful misreporting of data to hide problems that might result in punishment for the involved individuals. (Cao, Simon, 2011:26) In the post-1978 era the Chinese government reformed the statistical reporting system to regain control and increase reliability. The system has improved but there are still tendencies to overestimate output values. (Rawski, 2001:352)

According to the Princeton University professor Gregory Chow, (2006) recent Chinese statistical data are by and large reliable and useful for analysing the Chinese economy. However, he emphasises that some data is not trustworthy and that you need to be alert and cautions while working with the material (Chow, 2006:396-399).

While working with the Chinese Statistical Yearbooks I have kept this advice in mind, and checked for unrealistic results over the different time periods and provinces. I treat the data collected as a meaningful way of analysing Chinese innovation with reservation for statistical defects.

4.3 Dependent Variables

This study will use both Chinese domestic patent applications and granted applications as the dependent variables and as two proxies for innovation. The search for the optimal measurement of innovation is an on-going story and many economists have presented their indicators as the greatest measurement of innovation. There are also those that suggest that innovation is impossible to quantify and measure (Smith, 2005:149). The core of the measurement issues concerns defining innovation and measuring its components. An innovation is said to be something qualitatively new that offers new solutions in the economic and social spheres. But how "new" does the product, process or solution have to be to be called an innovation? And is it enough that the innovation is new to the market or does it have to be new worldwide? (Smith, 2005:149) This is a problem that innovation measurements handle differently, and the established indicators all have their positive and negative effects.

The three major established innovation indicators are research and development (R&D), patents and bibliometrics (Smith, 2005:152). R&D indicators are commonly based on the Frascati Manual 2002, a publication by OECD that has become a standard for R&D data gathering and handling. The R&D measurement determines innovation capacity based on the statistic data of R&D activity.

The positive features of R&D data measurement is the long time period of data registered and its standardization across countries (Smith, 2005:154). In this study the focus will be on a short time period, within a country. In other words, the primary positive effects of R&D data are not relevant in this study.

R&D data is also criticized of being an input value to create innovation rather than the actual output occurring in the economy (Crosby, 2000:256).

Another way of measuring innovation is with the bibliometrics approach. In this approach scientific research papers and publications are quantified. The interpretation of the bibliometric approach is that a nation where many scientific articles are published is by extension innovative. Bibliometric analysis is often used as a complement to patent or R&D measurements when measuring innovation, but alone it can be argued that it measures primarily the dynamic qualities of science and not innovation. (Smith, 2005. p. 153)

The third way of measuring innovation, and also the one chosen for this study, is quantity of patents. A patent is a public contract between an individual and the government, granting the individual limited time monopoly of an invention. The patent system is created as an incentive-mechanism for knowledge, invention and innovation creation. Without the patent system it would be less profitable to research new products, as the idea could be stolen directly after it enters the market (Britannica, 2012).

According to Smith (2005) patents have a striking advantage as an innovation indicator for the following reasons:

- Patents are granted for inventive technologies (i.e. innovation)
- Patent systems record important information about inventions
- The patent system provides a long history of recordings
- The data is freely available

Schmookler (1966) studied the correlation between patent and R&D expenditures finding the correlation being reasonably high. In Schmookler's study R&D expenditures were equivalent to patents as an innovation indicator. Crosby (2000) emphasises the role of patents in being a more efficient estimator of innovation than R&D expenditures because it registers the innovation output. Patents as a measurement for innovation also have weaknesses, the most obvious being tendency of patents to measure inventions rather the innovations. Patents will also miss innovations that are not patentable (Smith, 2005:160).

Patents can be divided in to two different categories, patent applications and granted patents; the first being all the applications sent in to a patent office, and the second just a measurement of all the patents that are granted.

In this study both of the measurements will be used in separate regressions in order to get a more dynamic result. It is argued that patent applications reflect actual innovative activity and granted patents are dependent upon the number of patent examiners (Schmookler,1966,Crosby, 2010). In the case of China, the government rewards patent filing and encourages application-submitting. It is argued that this generates many low quality patent applications that never get granted and were never intended to be on the market. Therefore, it is interesting to compare the results for both applications and granted patents.

The choice of innovation indicators is still not a trivial question and depends upon research object and data (Kleinknecht et. Al 2002) Patents will be used in this thesis as an indicator of innovation, hopefully it will generate a fruitful result like the many other studies using patent as a measurement for innovation. (Smith, 2005:160)

4.4 Independent Variables

4.4.1 Foreign Direct Investments

Foreign direct investments are as mentioned direct investment by a company in a foreign country. The variable used in this model summarizes the total amount of FDI in each Chinese region over a 5 years period. The FDI is counted in 100 million USD, but this is not of importance to the study, as all the values will be normalized to each region.

4.4.2 Science and Technology Industrial Parks

In this study innovation cluster activity will be estimated with Science and technology industrial parks (STIPs) projects quantity. STIPs are the main industrial clusters in China, spread across the Chinese regions and are host to approximately 50 000 tenants (Zhang, Sonobe, 2011:1).

There are numerous of other ways to measure industrial cluster activity and many studies focus on the concentration of enterprises. Common ways to measure industrial geographic distribution are Location quotient, Hoover Coefficient or Locational Gini Coefficient (Lu et al. 2011:2). Like many other indicators they all have their strengths and weaknesses. In this study we want to observe the relationship between patent and industrial clusters. A easy way would be to use data on numbers of industrial cluster in each region, but the problem is that industrial cluster are not a homogeny group. Industrial Clusters have different purpose, and not all of them are engage in research and development. Therefore I believe it is more appropriate to measure the cluster activity instead of the geographic concentration. I think STIPs projects quantity will be sufficient for the scope of this study, although it would be of interest to test different indictors in future studies. (O'donoghue, Gleave, 2004 p.419-429)

4.4.3 Intramural R&D expenditures

R&D investments will be approximated with intramural R&D expenditures, a measure for the total R&D expenditures by companies and by government means. This is a wide measurement of R&D expenditures and according to OECD the most efficient (OECD, 2002:107). According to Prodan (2005:5) R&D expenditures do not affect patent immediately and data should be lagged. How long time lag depends on the country but empirical studies presented by Prodan indicates 1-2 year lag is appropriate. I have tested different time lags and a two-year lag will be used, as it most efficiently fits the model later presented.

4.5 Control Variables

In the model control variables are included to prevent omitted variable bias, and to isolate the impact of our three variables of interest (Gujarati, Porter. p.231). The control variables chosen are proxies for commonly used macro variables that may affect innovation. They are included in the regression in order not to unobserved interfere with the results from the main variables. The control variables will be presented below with a short definition and the expected effect:

- *R&D Personnel:* Defined as the number of employers engages in R&D activity in each region.

- *Gross regional product:* a conceptual equal to GDP measuring the sum of value added generated by different economic activity in the regions.

- *Agriculture population:* the ratio of the population in each region engages in agriculture.

- *Torch program:* Programs for high-tech industries in China, the aim of the torch programs is to organize and develop high-tech projects and products for the domestic and foreign market. Torch activity in the regions is measured.

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- *Part of employed population that attended university:* Measuring the education level of the working force in the regions.

Table 2 shows a summary of the variables used and their expected effects.

Table 2

Variable	Type of variable	Expected sign
Patent granted	Dependent	-
Patent applications	Dependent	-
Foreign direct investments	Independent	Positive
R&D expenditures	Independent	Positive
Industrial cluster	Independent	Positive
R&D Personnel	Control	-
Gross regional product	Control	-
Agriculture population	Control	-
Torch program	Control	-
Part of employed population that attended university	Control	-
Urbanization	Control	-

4.6 Model

In order to preform a correct panel data analysis the regression model that will capture the effect of the independent variable upon the dependent variable is of great importance. As discussed in the method section, within-group fixed effect regression will be used in this study. To exemplify the regression, a simple model with one explanatory variable will be presented.

$$Y_{ij} = \beta_0 + \beta_1 x_{ij} + \alpha_i + \varepsilon_i \quad (1)$$

Consider this linear model (1) where i refer to the different region and j to different measurement within the region. α is the unobserved time-invariant effect, In this case the effect could be historical or institutional factors within the regions, unable to observe. The α is treated differently depending on choice between fixed and random effect but in this study we will continue to treat it as a fixed. Y is the dependent variable and X is the explanatory variable. β is the coefficient that reflects the effect of the independent variable upon the dependent variable. β_0 is the intercept and ε_i is the error term.

$$\bar{Y}_i = \alpha_i + \beta_i \bar{x}_i + \bar{\varepsilon}_i \quad (2)$$

$$Y_{it} - \bar{Y}_i = (\alpha_i - \bar{\alpha}_i) + \beta_i (x_{it} - \bar{x}_i) + (\varepsilon_{it} - \bar{\varepsilon}_i) = \ddot{Y} = \ddot{x}_{it} + \varepsilon_{it} \quad (3)$$

In equation (2) the mean value for the variables over time are estimated, and in (3) they are subtracted from the data and the region specific effect α is erased. The within-groups fixed effect regression model is specified. Explaining the variation about the mean of the dependent variable in terms of the variations of the mean of the explanatory variable (Wooldridge, 2011:220-225).

4.6.1 Model specification and discussion

The following models will act as tools for analysing our hypothesis in the panel data regression.

$$\log PatentA_{it} = \alpha + \beta_1 logFDI_{it} + \beta_2 logCluster_{it} + \beta_3 logR\&D_{it} + \beta_4 logGRP_{it} + \beta_5 logUnivA + \beta_6 logUrban + \beta_7\, logAgri + \varepsilon_{it}$$

$$\log PatentG_{it} = \alpha + \beta_1 logFDI_{it} + \beta_2 logCluster_{it} + \beta_3 logR\&D_{it} + \beta_4 \log GRP_{it} + \beta_5 logUnivA + \beta_6 logUrban + \beta_7\, logAgri + \varepsilon_{it}$$

- PatentA = Patent applications
- PatentG = Patent granted
- FDI = Foreign direct investments
- Cluster = Industry clusters
- R&D = R&D expenditures
- GRP = Gross regional product
- UnivA = employed population that attended university
- Urban = Urban population
- Agri = Agricultural as part of GDP

The models will estimate a linear relationship between the dependent and the explanatory variables using a fixed effect regression. The data was scatter plotted showing a non-linear relationship of the variables. This result interpret that another functional form is necessary. The best model fit is obtained in our regression by transforming all the variables to logarithm form.

A Hausman-test is performed in order to determine correct panel data model. Once again, fixed effect was proven to be the optimal panel data alternative for this study. A redundant fixed effects test is preformed in order to control if the cross-section or period-section fixed effect application is redundant. The result shows that the cross-sectional is redundant and the specification is removed from the regression (Eviews, 2009:56)

A variety of other tests have been applied to analyse the sustainability of the model. Heteroskedasticity and autocorrelation are common problems in panel data sets, in this set autocorrelation was detected during a graphically examination. The negative effect of autocorrelation that makes the regression inconsistent was corrected by applying Period weights (PCSE) to the regression. The residuals were tested for non-normality distribution and multicollinearity, neither of the effects was observed (Westerlund, 2005:150-160).

5 Analysis and Results

In this section the result of the previously described model are presented and analysed. Adjusted R-squared, number of regions and observation are also included. The main focus will be on the independent variables presented earlier: R&D expenditures, foreign direct investments and cluster activity. In the following section these results will be discussed and compared. In regression (1) 'patent applications' is the dependent variable. In regression (2) 'patents granted' is used. Both of the regressions have the same independent variables included in the result.

Independent Variable	Regression (1)	Regression (2)
R&D expenditures	0.716610***	0.577850***
	(0.077278)	(0.079696)
Industrial clusters activity	-0.019644	-0.083604**
	(0.033461)	(0.035186)
FDI	0.059086	0.091999**
	(0.049216)	(0.049454)
R&D personnel	-0.023361	0.081862**
	(0.055100)	(0.048247)
GRP	0.439430**	0.364042*
	(0.153961)	(0.166636)
Agriculture population	-0.008331	-0.015301
	(0.224664)	(0.232065)
Torch projects	0.007061	-0.002059
	(0.038509)	(0.043570)
University attended	-0.250434*	-0.138370
	(0.137261)	(0.141267)
Urbanization	0.605517	0.404471
	(0.399104)	(0.427728)
Observations	155	155
Regions	31	31
Adjusted R-squared	0,8312	0,8023

Note: Standard errors in parentheses. The asterisk represents significance. *** = 1% ** = 5% * = 10%

5.1 Regression Results

Two regression results are presented in this study, and they show two sides of Chinese innovation. In the first regression two of the three variables that are relevant to my hypothesis are insignificant. This confirms the hypothesis about a positive relationship between R&D expenditures and innovation, but rejects the hypotheses that FDI and cluster activities have a positive effect on innovation. In the second regression, the same hypothesis is tested with the same explanatory variables, but with a different dependent variable. In this regression all three of the variables show significant results, confirming the hypothesis that they have a positive relationship with innovation.

As argued earlier, all the variables have been logarithmically transformed and therefore the coefficients are interpreted in terms of elasticity. This means that a 1% change in the explanatory variable generates a percent-change in the dependent variable equal to the coefficient of the explanatory variable.

The R-square value, also called the determination coefficient measures the proportion of the variation in the dependent variable explained by the explanatory variables. However, the R-squared value can also be a pit-fall in a regression analysis, as it cannot always be trusted. The reason for this is that the R-squared value increases when more explanatory variables are added. If the underlying theory does not support all the variables included in the model, they may be irrelevant for the model but still boost the R-squared value. To prevent this, the adjusted R-squared value is preferable. The adjusted R-squared value is used in this analysis as the most accurate coefficient of determination, since its value is not as dependent upon the quantity of explanatory variables (Gujarati, 2009:113-138). Underlying theory supports the variables used in the regression and the adjusted R-squared value can be interpreted as correct.

The adjusted R-squared in regression (1) is 0.8312. This can be interpreted as about 83%, meaning that the logs of the independent variables included in the regression can explain 83% of the variation in the log of patent applications. In regression (2) about 80% of the variation is explained by the included variables. The R-squared value is quite high for both of the regressions, emphasising that the regression efficiently reflects the relationship between the dependent and explanatory variables.

Hypothesis 1: R&D expenditure has a positive relationship with innovation.

R&D expenditures have a statistically significant positive relationship with both of the different types of patent regressions. This result confirms the first hypothesis about the positive aspects of investing in R&D in order to increase innovation. The result supports the discussion of the theory chapter, that R&D

activities have become a more predictable source of innovation creation. Also, Chinas strategy of increasing R&D expenditures in order to create innovation seems like a fruitful idea. The coefficient value indicates that the relationship between R&D and innovation is not 1:1.

This means that a 1% increase in R&D expenditures leads to less than 1% increase in patent. The relationship is still positive but in order to increase innovation by 1% R&D expenditures need to be increased by more than 1%. This result supports Griliche's theory that a part of research expenditures go to unsuccessful projects. In general, the result of both of the regressions is in line with previous empirical studies presented in the theory chapter and the first hypothesis is accepted.

Hypothesis 2: Sectorial industry cluster has a positive influence on innovation.

Science and technology parks' activity (STIP) has a slightly negative coefficient. It is also insignificant in one of the regressions; in regression (1) the result is insignificant and in (2) it is significant at a 5% level.

The interpretation of regression (1) is that it is not possible to draw any conclusions about the impact of cluster activities on patent applications. The negative coefficient could be registered by chance. This could mean that Chinese applications do not reflect innovation properly, and that the large amount of applications does not correlate with industrial cluster activity.

In regression (2) the STIP variable is statistically significant with a negative coefficient close to zero. Although it is significant in the second regression, the negative coefficient means that the hypothesis must be rejected. The significant result of this regression could mean that the measurement of patents granted better explains the relationship between industrial cluster activity and innovation than patent applications. As mentioned earlier, the Chinese government rewards patent filing. This may have lead to an overwhelming quantity of patent applications that does not sufficiently correlate with the explanatory variables. In this case patents granted are a superior measurement of cluster activities relation to innovation as it is significant. However, the second hypothesis, which expected a positive relationship between cluster activity and innovation, must be rejected in both cases.

The studies presented in the theory chapter emphasise that clusters are an overrated platform for innovation creation are in line with this result in regression (2). The results of the regressions indicate that companies and institutions gathered in Chinese clusters do not have any advantage as innovation creators. This could be in line with the theory presented by Porter, that homogeneity and group thinking can occur in industrial clusters, resulting in fewer new ideas. Another interpretation could be that Chinese innovation development through industrial parks is, as previously mentioned, quite a new phenomenon and that it has not yet reached its full potential.

Hypothesis 3: Foreign direct investments generate spill over effects that have a positive effect on Chinese innovation

Foreign direct investments show a non-significant relationship in regression (1) and a positive significant relationship in regression (2). This means that the third hypothesis is rejected in the first case but not in the second. Why are, once again, the coefficients of the explanatory variables more significant when patent granted is used as a dependent variable than when patent applications is used? The reason can be, as discussed earlier, patent applications' low quality as an innovation indicator. However, it can also be the other way around, that patented granted indicates a relationship that does not exist in reality, and patent application is the most sufficient measurement for innovation. However, theories and literature previously mentioned strongly indicate that FDI should have an influence on innovation. Therefore I judge patents granted to be the best estimator, making the results of the second regression more reliable than the first.

According to the result of regression (2), A.C Pigou's theory of externalities can be applied to FDI spill-overs in China; more FDI generates more Chinese innovation. It is likely that the knowledge transmission channels discussed in the theory chapter are involved in this exchange, as they have been empirically observed before. The FDI coefficient is close to zero, indicating that FDI has a weak impact on patents granted. This can be the result of the adaption theory, that countries have different capabilities to accumulate knowledge. In China's case, it could be that the opportunity for FDI is quite new. Before the economic reforms, few foreign companies were allowed to be present in China. As a result the transmission channels may not be fully developed. For example, one reason could be that personnel at foreign companies in general do not speak Chinese, and the transmission to Chinese companies therefore is inefficient.

5.1.1 Control Variables

In this section the control variables and their impact on the regression results will be discussed. The control variables are included in the regression in order to clarify and isolate the result of the independent variables.

In regression (1) R&D personnel, agriculture population, torch projects, and urban population are all insignificant variables. As they are control variables included to prevent omitted variable bias, an alternative could be to drop them out of the model in order to clarify the result. (Gujarati, 2010: 231) This has not been done, as the model does not contain many variables and the result is easy to view.

In regression (2) GRP, Agriculture population, torch projects, university attended and urbanization are insignificant. They have been treated the same as the variables in the first regression and their results have been presented.

There are more significant control variables in the second regression than in the first. This indicates that more information about the relationship between innovation and the explanatory variables has been captured.

GDR and employed university attenders are significant in regression (1). GRP has a positive coefficient, indicating that richer regions innovate more. This can interpreted as richer regions being able to afford to focus more on innovation-related activities than less developed regions. They do not have to dedicate all resources to basic needs like poor regions, and this positively affects innovation.

Employed population with university degrees have a slightly negative effect on a 10% significance level. This could indicate that less qualified personnel generate more innovation. From a theoretical standpoint this can be seen as complete nonsense, and the result is difficult to justify. The 10% significance level indicates that it is a rather weak relationship. This could imply that the data used is of poor quality, and as mentioned before, Chinese statistics should be treated with caution. For instance, the number of employees with university degrees could be overestimated in the data, resulting in a disproportionate relationship between university degrees and patents granted.

In regression (2) the quantity of R&D personnel shows a positive significant relationship with innovation. This variable is similar to R&D expenditures but interpretation could be quite different. The result indicates that the quantity of researchers is of important for innovation creation.

5.1.2 Result Summary

The result of the regressions gives us a mixed idea of how FDI, R&D expenditures and industrial cluster impact innovation. The idea discussed in the variable chapter regarding patent applications being a weak estimator for Chinese innovation, can be confirmed. Many explanatory variables show insignificant or theoretical nonsense results with patent applications. It is more likely that this is the result of patent applications being a poor or inaccurate indicator of innovation. This is particularly relevant to China, where, as previously mentioned, the government has worked to increase patent applications. This is in itself an interesting aspect of the discussion about Chinese innovation, since it could be an indicator that the stimulants that the Chinese government has used may have increased the number of patent applications, but not actual innovation.

The results from the patents granted regression better fits with previous theoretical and empiric studies. In this regression all of the three independent variables are significant, and two of three hypotheses are confirmed. A possible interpretation of this is that Chinas fifteen-year program to increase innovation is rather accurate. According to the result of the second regression, R&D expenditures have a positive relationship to innovation. FDI has also a positive relationship, indicating that more foreign companies situated in Chinese regions increase innovation. Industrial park activity has a slightly negative coefficient, indicating that there are no positive effects of cluster activity.

6 Conclusion

This study has provided some insight into the factors that create innovation in China. The focus of the study has been on analysing the impact of R&D expenditures, FDI and Industrial cluster on Chinese innovation. Innovation is in the study approximated with both patent applications and patent granted. The result from the empirical study indicates that patent granted is a better choice when measuring Chinese innovation.

The study proves that R&D expenditures and FDI are positively correlated with innovation in China. This confirms two parts of my hypothesis. This result is also good for the Chinese government, which actively supports innovation through these two channels.

Industrial cluster activities have a slightly negative relationship with innovation, which indicates a lack of efficiency of industrial clusters in China when it comes to innovation. The reason for this could be that homogeneity in the clusters does not generate new ideas and that it prevents innovation. The result can also indicate that Chinese industrial clusters have not yet fully developed their innovation and creative potential.

Most of the theoretical framework used to analyse innovation in China was developed by economist situated in Europe and the USA. I believe that a interesting approach for another study would be to use the thoughts of Asian economist. they have a closer relationship to the region and can more efficiently analyse the effects that creates innovation. Networks and personal relationships are examples of factors that probably would get more attention in Asian innovation theories.

7 References

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8 Appendix

Fig.1 (huang, et al. 2004)