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Innovation and transformation in the Swedish manufacturing sector, 1970-2007

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Karolin Sjöö

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Preface

It is the 10th of June 1997 in Trollhättan, Sweden. Thousands of excited people have gathered on an endless asphalt plain under the summer sun. A considerable number are enjoying the ice-cream launched by the local ice-cream manufacturer for this special occasion. The date is carefully chosen, 50 years have passed since Saab Automobile began manufacturing cars. The location is carefully chosen, it is in the middle of the former Nohab factory area. Nohab, a locomotive manufacturer, was an important driver of local growth until the 1970s. On a podium under a black piece of cloth stands the engine of future growth ready to be unveiled. It is the new Saab Automobile model, the first new model since 1984 and expectations are sky-high. It is not only a car; it is a vehicle of promises, of renewal and prosperity.

I am 13 years old and the mint and chocolate ice-cream tastes great. Equally exhilarating is the feeling that *the* firm of my hometown is at the forefront of technology and innovation; the sensational fact that the parents of my friends and schoolmates have constructed a car so modern and innovative, that it is destined to conquer the world!

Fast forward to 2009. The Scanian December fog engulfs the school of economics. Christmas is only a few days away and I am in an Excel coma. Before heading out to the lunch room, I take a quick look at the news. I text my mother, who was at that time a SAAB-employee: "Is it true?" A few anxious seconds of waiting follow. "It's true". General Motors was to liquidate Saab Automobile.[1] Just as shiny and bright as the future looked that summer day in 1997, as dull and depressing it appeared in December 2009.

[1] It turned out that this was just one step in a lengthy process towards bankruptcy.

While university has taught me a lot about processes of creative destruction and structural change, acquired knowledge is not the only force going into this thesis. Growing up in a town where a single manufacturing firm is highly important to social cohesion has left me personally with an emotional interest in the manufacturing sector.

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VINNOVA funded the SWINNO (Swedish Innovations) project of which this thesis is a product. For that, and for the interest and enthusiasm that representatives of VINNOVA have shown, I am truly grateful. Göran Marklund, Joakim Appelqvist, and Rolf Nilsson have all been important to the realization of this project. Many more have partaken in discussions of the progress and results of it. Thank you!

The SWINNO project has involved the construction of a large database. My partner in this labor intensive venture into the archives has been Josef Taalbi. Together we have spent countless hours going through primary sources, putting the data together, and discussing its quality and drawbacks. I have been lucky to have shared this process with such an intelligent person. With regard to the collection of source material, special thanks goes out to Björn Eriksson, Josephine Fischer, Jonas Lilja, Johanna Conradsson, Jacob Littorin, Emelie Weijman Hane Jansson, Ann-Sophie Larsson, Johanna Jeppsson who all assisted in parts of the data gathering process. The database could not have been constructed without the helpful and service minded personnel at the University library (UB). Thanks for putting up with endless

requests and having our dusty journals cluttering your workspace. A special thanks goes to Björn Nyhlén, our man in the library depot. With regard to the craft of literature-based innovation database construction, Josef and I have had the benefit to learn from Jani Saarinen, Nina Rilla, and Robert van der Have. Jani has mentored us and shown great interest in our work. Nina and Robert have always been curious and willing to discuss methodological matters. We have also been lucky enough to discuss such matters with Alfred Kleinknecht. Data supplied by SCB has added a significant amount of quality to the SWINNO database. We appreciate the way Werkisa Wajira has done his outmost to meet our demands.

A database does not make a thesis. When it comes to the writing process, I have had the privilege of receiving constructive comments and criticisms from a set of intelligent researchers in addition to my supervisors. The input given by Lars Svensson and Martin Shrolec at my final seminar was invaluable and a great guide in the last phase of work that would complete the dissertation. I highly appreciate the time Lennart Schön has put into reading and making comments on matters large and small; those comments have certainly helped to improve the final text. I have also been lucky to have received perceptive and stimulating comments from Gunnar Eliasson. I am grateful to Kerstin Enflo who has commented on drafts, brought clarity to statistical matters, and cheered me on. I am indebted to Fredrik N G Andersson for helping me out with the wavelet transformation in chapter five and to Seán Kenny for proofreading the text. I could not have wished for more enthusiastic engagements, all errors remaining in the text are my own.

Thesis writing is a lonely business. I am grateful to have had the colleagues at the department of economic history; senior researchers as well as fellow PhD students, surrounding me during these years. Birgit Olsson, Ingrid Prödel-Melau, Tina Wueggertz, and Kristin Fransson have been indispensable in all practical matters. Daniel Yllas has enabled my bicycle commute, mil gracias! I am happy to have spent a year of my PhD training at CIRCLE (Centre for Innovation, Research, and Competence in the Learning Economy). CIRCLE offered a welcoming environment, interesting discussions and seminars enabled by a critical mass of innovation researchers. CIRCLE also gave me the 'this-scares-the-shit-out-of me-but-I-cannot-*not*-do-it' opportunity to discuss my research with the visiting innovation research legend Richard Nelson.

Friends and family have been consistently great sources of support and perspective. While all of you have been cheerful and supportive, some of you have played more of a day-to-day or practical role in the process of finalizing this thesis. Kajsa has been around from the beginning at A level in Economic History and is a warm and loyal friend. Elin has been around from day one back in 1983 and is a constant source of comfort and joy. The homes of Jitka and Erik were much needed rural sanctuaries when I was stressed-out or merely in need of feeling grass between my toes. Ulf and Viktoria enabled one of my most productive months when they let me stay in their house in Åre in June 2013. Thank you!

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1. Introduction

Change and fluctuation characterize the capitalist economy; production structure changes and extended periods of relative prosperity are followed by periods of relative decline, and vice versa.[2] The roaring 1920s, the Golden Age, and the second half of the 1980s are all considered periods of general economic upturn. Classic examples of periods of economic decline typically include The Great Depression, the 1970s, and the recent slowdown of the world economy which began with the global financial crisis of 2008.

Over the course of the rollercoaster-like 20th century, the economies of the developed world have undergone profound structural change with regard to the nature of the output being produced, the identity/composition of the producers/employees, and the means of production. Structural change and fluctuations in economic growth are not separate phenomena. Nobel laureate Simon Kuznets has suggested that a high rate of economic growth is associated with a high rate of shift in production structures.[3] One of the most commonly suggested catalysts of both economic growth and structural change is technical change.[4] Technical change refers to changes in

---

[2] In addition to longer periods of prosperity and decline, the economy is subject to short term periodicity (i.e. business cycles).

[3] Kuznets 1971 p. 322-33

[4] Although classical economists like Adam Smith (1776) and John Stuart Mill (1848) recognized that technical change was central to economic growth, it was not until the 1950s that economists began to understand the extent to which this was the case (see e.g. Abramowits (1956), Kendrick (1956), and Solow (1957) for early contributions to the growth accounting literature). Having taken the growth of input factors such as capital and labor into account, it was found that a large portion (between 80 and 90 percent) of the growth in total factor productivity remained unexplained (See Abramowitz 2003). In addition to technical change, suggestions as to what comprises the so called "residual" include for example growth in human capital, economies of scale, and a more efficient allocation of resources (see Kendrick (1961), Denison (1962), Solow (1963), and Jorgenson and Griliches (1967). See Hulten (2001) (the first half of the chapter) and Abramowitz (2003) for overviews (the latter more accessible than the former) for the history of growth accounting.

techniques and the knowledge, learning, imitation, and diffusion thereof.[5] New technology, through the practical application of scientific knowledge, is part of that technical change. Economic historians traditionally posit that such new applications are inextricably linked to economic development and growth.[6] The steam engine is for example widely considered to have been important to the takeoff of industrialization in 18th century England. The more disruptive technology in contemporary times is the microprocessor. At the other much less revolutionary end of the spectrum we find technologies with local and/or only marginal effects. While we usually talk of structural change and economic growth in the aggregate sense, new technology which is a central driving force of these has local origins. While at the macro level technical and technological changes are manifested by a shift in the aggregate production function, at the micro level this is physically tangible. New technology is generally incorporated in innovations put out on the market by business firms or individual entrepreneurs. Business firms and entrepreneurs are thus cornerstones of the capitalist economy. Knowledge regarding historical changes in innovation output of such actors is hence an important key to our understanding of economic development and growth in past, recent and present times. Naturally, this would also apply to future growth and development to some extent.

The aim of this thesis is to capture and analyze changes in the volume and character of innovation output during the final three decades of the 20th century and the first seven years of the new millennium against the backdrop of fluctuations in aggregate economic growth and received accounts of structural change. In particular, the aim is to investigate whether changes in certain quantitative and qualitative aspects of innovation output are generally associated with extended periods of relative prosperity and decline. The objective is attained through investigations of time series data

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See Aghion and Durlauf (2005) for an overview of the state of the art and see Crafts (2009) for an overview of economic history contributions that have made use of growth accounting techniques.

[5] Technique comes from the Greek work *techne* which have several definitions including craftsmanship, craft, and art.

[6] See e.g. Landes (1969) and Mokyr (1990a, c).

of innovation output with regard to temporal, firm size, and industry patterns covering a period including long-term fluctuations in economic growth as well as profound structural change. These three aspects of innovation output are related to the following basic research questions: *when* did firms innovate? *who* were the innovating firms? and, what *kind* of innovations are we referring to? We are thus approaching change in innovation output from three different perspectives.

Our knowledge of innovation output is primarily based on proxy measures such as R&D spending, patent and productivity statistics, or self-reported assessments of innovation activity and output. There also exist plentiful accounts of rejuvenation through innovation with regard to specific firms or industries. While aggregate statistics, surveys, and case studies are indispensable, observations of actual innovations are better equipped to capture quantitative and qualitative changes in innovation output. This thesis explores a new dataset containing close to 4000 observations of actual innovations. The innovations were all observed in trade journal articles. The new data allows us to study quantitative and qualitative aspects of innovation output at the micro level. The information available in the database includes the year the innovations were commercialized, their origin, technological and functional characteristics, novelty, information about the innovating firm etc. The innovations in the database originate from a particularly national and historical context; the Swedish manufacturing sector between 1970 and 2007.

1.1 The case: economic growth and industrial transformation in Sweden, 1970-2007

For over a century resource extraction and processing together with groundbreaking progress in engineering provided the basis for sustained and comparatively strong Swedish economic growth. However, few things last forever and this situation proved no different. By the second half of the 1970s considerable parts of the Swedish manufacturing sector seemed to be significantly misaligned and out of sync with the environment.[7]

[7] Lundberg 1983 p. 27-30; Schön 2000 p. 468-70, 489-93.

Traditionally strong industries such as shipbuilding as well as iron and steel faced severe difficulties as the world economy slowed down and international competition intensified. This malady plagued the Swedish economy; productivity growth was meager, revenues nose-dived, and numerous important establishments were closed down. The passage of time revealed that the downturn was not the result of a short-term swing of the business cycle but rather was a symptom of a profound structural crisis that required far-reaching restructuring and a transformation of the manufacturing sector. Firms within major parts of the sector were faced with the pressing need to regain competitiveness. This period of slowdown, stagnation, and imposed transformation was prolonged; not until after the passing of a deep financial crisis experienced in the early 1990s did Swedish economic growth take off significantly again. From the mid-1990s until the recent slowdown, growth of the Swedish economy has been relatively strong by international comparison.

Ever since the publication of the American journalist Marquis W. Childs' book *Sweden: The Middle Way* in 1936, the Swedish case has attracted a lot of attention among foreign policy makers, journalists, and academic onlookers. This curiosity stemmed primarily from Sweden's achievement of relatively strong economic growth, near full employment, high welfare expenditure, and a fairly equal income distribution. International interest was generated by the questions of how all of these factors had been achieved simultaneously and how the system was successfully implemented in practice.

Until the slowdown of the 1970s, the so called *Swedish model* was largely a concept with positive connotations. The Swedish economist Assar Lindbeck pondered the international attention:

> "Why should foreign observers be interested in economic and social conditions in Sweden? The best answer is probably that institutions and policies in Sweden have been rather experimental, and that some of these experiments may also be relevant for other developed countries. Sweden may

> therefore be seen not only as a small country on the periphery of Europe, but also as a large ("full-scale") economic and social laboratory".[8]

The stagnation of the Swedish economy during the 1970s and 1980s led to renewed international interest; what caused Sweden to fail? There was both curiosity and cynical remarks. The standard received answer revolved around the same institutions and economic policies that had engendered prior success. Mancur Olson, one of the more influential foreign academic commentators, suggested that long-term political stability had allowed encompassing interest groups (i.e. labor unions) to grow so large that they eventually devolved into narrow special-interest groups whose influence obstructed flexibility and structural adaptability.[9] According to Olson, Sweden as well as several other Western European economies were subject to "institutional sclerosis".[10] Domestic academic commentators spoke to Olson and labeled the Swedish problems "Suedosclerosis", a particularly severe strain of "Eurosclerosis".[11]

---

[8] Lindbeck 1997 p. 1273. Though Swedish experimentation, institutions and policies may have interested a variety of audiences, questions regarding the relevance of these experiments to other countries can be raised. Contributions to the varieties of capitalism literature argue that there are possibilities to group countries with similar institutional set ups (see e.g. Hall and Soskice 2001; Amable 2003; Mjøset 2011). Amable (2003) for example, suggests that there are five different types of capitalism; the market-based model (e.g. U.S. and U.K.), the social democratic model (e.g. Sweden and Denmark), the continental-European model (e.g. Germany and Austria), the Mediterranean model (e.g. Spain, Portugal, and Greece), and the Asian model (e.g. Japan and Korea). Amable's (2003) generation of these five models was based on similarities in institutional factors such as product and market regulation, the financial intermediation sector and corporate governance, social protection and the welfare state, and the education sector. To the extent that it is possible to generalize the findings presented in this thesis, such generalizations should consider countries with a reasonably comparable institutional set up. Still, similar institutions do not suffice to make the innovation output of two countries eligible for comparison; sectoral composition, industrial specialization, demography etc. are all factors likely to affect innovation output. With respect to the above mentioned factors, a comparison with Finland is closest at hand (Andersson and Krantz 2006; Hagberg et al. 2006). The concluding chapter will return to the possibilities of just such a comparison.

[9] Olson 1982, 1990, 1995, 1996. See also Lindbeck (1983) for a comment on the productivity slowdown of several European countries.

[10] See Olson (1996) for a discussion of different expressions of institutional sclerosis.

[11] Ståhl and Wickman 1993, 1994

Recently, observers in the international sphere have once again turned their eyes to Sweden. The handling of the deep crisis in the early 1990s, the strong growth thereafter, and the comparatively positive faring of the Swedish economy in the recent global financial crisis has attracted attention.[12] Professor Emeritus Fred Bergsten, writing for The Washington Post, calls Sweden a "paragon of sensible economic and social policy".[13] The pendulum has swung; from being regarded as a role model to a child of sorrow, Sweden is now once again considered a role model.

Although the varying fortune of Swedish economic performance has attracted considerable attention internationally, the overwhelming majority of received analyses are of Swedish origin. Intriguingly, the domestic body of literature does not deliver one uniform answer with regard to the association between the long term economic growth fluctuations, structural change, and micro level activity. Two quite different positions are distinguishable in this literature. One stays close to the Olsonian view in arguing that the Swedish economy suffered from a structural lock-in in the 1970s and 1980s. The other, challenging perspective, suggests that these decades saw profound structural transformation at the micro level. In this perspective, slow growth is the unavoidable cost of transformation. Chapter three explores the two positions in some depth. The empirical findings presented in the thesis will be discussed from the point of view of these two different positions.

This analytical approach is captured by the concept of *triangulation*. In trigonometry or geometry, triangulation is used to establish the distance to a third coordinate by referring to the distance between two given coordinates. In social sciences, triangulation is used to increase the validity and reliability of findings by for example employing multiple sources of data, methods, or theories.[14] An analytical triangulation requires two received analytical accounts of the phenomenon under investigation, and the establishment of the relation between those two interpretations. The two interpretations can then be used to analyze a new source of information about the

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[12] Dougherty 2008; The Economist 2009; Irwin 2011; IMF 2012; Bergsten 2013. See also Calmfors 2013

[13] Bergsten 2013. Jonung in several works has engaged in communicating the keys to the successful crisis policy (2008, 2009).

[14] See e.g. Patton (2002).

phenomenon. The result of such a triangulation should provide a relatively valid and reliable representation of the phenomenon in question. The resulting imaginary triangle could have all sorts of forms depending on whether the new findings support or contradict the received accounts.

By way of the new data and an *analytical triangulation* of the pattern found therein, the ambition of this thesis is to answer the following overarching research question:

Is structural transformation of the manufacturing sector -as demonstrated by changes in the quantity and character of its innovation output- associated with fluctuations in the long term Swedish economic growth rate?

While the overarching question addresses a particular empirical context, there exist long-standing and encompassing academic debates about the three aspects of innovation output that will be investigated in the thesis (temporal, firm-size, and industry distribution). The research questions of the thesis (when? who? what?) have to be anchored in these debates. The remainder of this introduction is structured as follows: section 1.2 discusses the concept of innovation, section 1.3 reviews the literature on the temporal, firm size, and industry distribution of innovation, and gives further specification of the three research questions that will be answered in the thesis. Section 1.4 discusses the limitations of the present study and section 1.5 closes the introductory chapter by introducing the rest of the thesis.

1.2 The concept of innovation

For a long time, the phenomenon of innovation was poorly understood. In economics, innovation was part of the so called "residual".[15] Today, it is a quite well-researched phenomenon.[16] It has also become a true buzzword.

[15] Rosenberg 1982; Abramowitz 2003 p. 36-9. See footnote number four.

[16] Fagerberg and Verspagen 2009; Fagerberg et al. 2012

Nonetheless (or *because* of this development), some remarks have to made about the concept as it is understood and used in this thesis.[17]

While innovation and invention are sometimes used interchangeably, Joseph Schumpeter, whose writings can be considered a prelude to innovation studies, argues that innovation must be distinguished from invention because the latter does not in itself imply any commercial relevance or value. An innovation, on the other hand, is always found in the commercial sphere.[18] Accordingly, this also implies a focus on the innovator (the agent who brings the innovation into the commercial sphere) rather than the inventor. In addition to the commercial dimension Schumpeter defines innovation as "the carrying out of new combinations".[19] As long as the combinations of components are novel, the components do not have to be new per se. Thus, according to Schumpeter an innovation is a novel combination of components in an economically relevant way.[20]

The concept of innovation is not restricted to the domain of products. An innovation can also be a new way to process material, to organize activities, or a new service offering.[21] Innovations (in the strict sense of the term; i.e. commercialized) of all types are represented in the dataset that is being explored in this thesis. All innovations in the database are traded on a market and thus irrespective of whether they are products, processes, services or something else, they are treated as part of the product portfolios of the innovating firms (i.e. they are intended to be sold). However, the data has a strong product bias.

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[17] In a Wall Street Journal piece, Kwoh (2012) argues that the word 'innovation' has lost its true meaning in modern language due to overuse.

[18] Schumpeter 1934 p. 65ff

[19] Schumpeter 1934, p. 65

[20] Fleming 2001; Rosenkopf and Nerkar 2001

[21] Fagerberg 2005; OECD 2005. Schumpeter (1934 p. 66) defined product innovation as "the introduction of a new good -that is one with which the consumers are not yet familiar - or a new quality of a good" and a process innovation as "the introduction of a new method of production, i.e. one not yet tested by experience on the branch of manufacture concerned, which need by no means to be founded upon a new scientific discovery and can also exist in a new way of handling a commodity commercially".

Sales are one of the prime ways in which a firm interacts with its social and economic environment.[22] One consistently significant challenge for managers is the organization of firm product portfolios so that the best possible fit with the environment is achieved.[23] Scott (1981) notes that "the best way to organize depends on the nature of the environment to which the organization must relate".[24] Miller and Friesen (1983) argue in a similar vein that the viability of firms depends on "their ability to master the challenges posed by their environment" and furthermore that "organizations must modify their structures to cope with the additional information processing requirements invoked by more dynamic, hostile or complex environments

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[22] Levinthal and March 1981; Teece et al. 1997; Mintzberg et al. 2009 p. 318

[23] With regard for example to competitors, the supply of raw material and other input factors, regulations etc. Lawrence and Lorsch 1967; Thompson 1967; Child 1972; Lawrence and Dyer 1983; Hrebiniak and Joyce 1985; Lant et al. 1992

[24] Scott 1981 p. 114. Scott touches on the issue of whether managerial choice or environmental determinism supersede the other as the determinant of the configuration of a firm (Astley and Van de Ven 1983; Hrebiniak and Joyce 1985; Burgelman 1991). Structuralist theories as developed in the industrial organization literature leave much less room for managerial choice than do the strategy and management literature. According to mainstream industrial organization theory, firm behavior is determined by a range of structural industry characteristics such as number of sellers and buyers, product differentiation, barriers to entry, degree of fixed versus variable costs, vertical integration, appropriation possibilities etc. (Scherer 1980; Kamien and Schwartz 1982; Levin et al. 1985; Tirole 1988; Conner 1991). The relationship between firm output and industry variables has been expressed in the so-called structure-conduct-performance hypothesis (Bain 1956, 1959; Needham 1978; see Mason (1939) for an early formulation). Structuralist Michael Porter's work on firm strategy has influenced both scientific researchers and practitioners. Porter postulates that firms in the same industry are likely to face similar conditions in terms of international competition, wage levels, prices of other inputs, regulatory framework, monetary policies, and other factors. More than any other factors, Porter emphasizes the threat of new entrants or substitution, and the bargaining power of suppliers and buyers (1980). Contributions in the industrial organization literature have addressed two themes more than others; the relationship between general firm performance and industry concentration and size respectively (Cohen and Levin 1989). Few accounts regard the relationship between *innovation* performance, concentration and size (Cohen and Levin 1989; Schmalensee 1989). Contradictory results have dogged the industrial organization literature (Conner 1991; Malerba 2005; Einav and Levin 2010; Schmalensee 2012). Levin et al. (1985) suggested for example that concentrated industries, with low uncertainty and a stable inflow of capital would make firms more prone to engage in R&D. Geroski (1994 p. 59) however, did not find such a correlation. Hrebiniak and Joyce (1985 p. 336-7) advise against making a binary distinction between managerial choice and environmental determinism but rather conceive of the two as complementary.

(or they must somehow avoid these environments)".[25] A dynamic environment requires firms to be able to update their product portfolios (and any other central aspect) in order to sustain a good fit, and in the long run, to survive. The capacity to undertake timely update of the product portfolio has been called a *dynamic capability*.[26] Dynamic capabilities are in short "an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions".[27] Lumpkin and Dess (1996) define innovativeness as a reflection of "a firm's tendency to engage in and support new ideas, novelty, experimentation, and creative processes that may result in new products, services, or technological processes. Although innovations can vary in their degree of radicalness, innovativeness represents a basic willingness to depart from existing technologies or practices and venture beyond the current state of the art".[28] Influenced by Miller and Friesen (1983), Lumpkin and Dess (1996), and Teece et al. (1997), this thesis defines innovation as *a firm's means to update or modify the structure of the product portfolio in order to sustain and/or improve the existing fit in a dynamic environment.*[29]

Updates or modifications of the structure of the product portfolio can range from minor to major. This spectrum may be addressed with measurements of innovation novelty; high novelty signals a major update of structure whereas low novelty signals a minor modification. Innovation novelty is a matter of degree and yet, the majority of the received typologies are dichotomies, not spectrums.[30] This thesis approaches novelty from the point

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[25] Miller and Friesen 1983 p. 230. March (1991 p. 80) argues likewise that "exogenous environmental change makes adaption essential". Dess and Beard (1984) describe the environment of a firm as being characterized the following set of parameters; munificence (its capacity to support sustained growth), dynamism (its stability or turbulence), and its complexity (its homogeneity and the ease with which information is acquired and interpreted).

[26] Teece et al. 1997

[27] Teece et al. 1997 p. 516

[28] Lumpkin and Dess 1996 p. 142

[29] Miller and Friesen 1983; Lumpkin and Dess 1996; Teece et al. 1997

[30] Dichotomies typically regard to the extent a given innovation alters current structures in terms for example of knowledge, technology, and organization (Abernathy and Clark 1985; Tushman and Anderson 1986; Christensen 1997). Dichotomies found in the literature

of view of the world market and from the point of view of the innovating firm. According to a world market perspective, innovations can range from blending with a set of equivalent products to being distinguished and truly cutting edge. A new-to-the-world innovation is assumed to represent a major modification of the structure of the innovating firm's product portfolio.

One of the more common typologies employed to assess firm novelty is based on the concept of 'organizational search'.[31] The behavioral theory of

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include for example revolutionary versus evolutionary, radical versus routine, new versus extension, original versus adapted, pioneering versus modifying, basic versus improvement, and discontinuous versus incremental. The more famous distinction is that between incremental and radical innovation. The distinction is fed by the idea that technological change is cumulative and thus implies that the development of technology follows specific trajectories (Dosi 1982). An incremental innovation is one that takes a small step along the trajectory while a radical one makes a leap or overthrows the trajectory. The guides of progress in searching for new innovations bound to a specific trajectory have been called technological regimes (Nelson and Winter 1982), technological paradigms (Dosi 1982), techno-economic paradigms (Freeman and Perez 1988), and technological guideposts (Sahal 1981). Dosi (1982) defined a technological paradigm as "an outlook, a set of procedures, a definition of the relevant problems and of the specific knowledge related to their solution" (p. 148). As an example, the most relevant problem for the future development of the petroleum-driven internal combustion engine is enhanced fuel efficiency. Incremental change is given by refinement, improvement and the exploration of knowledge in the neighborhood of existing knowledge (Myers and Marquis 1969; Gatignon et al. 2002). At the opposite end of the spectrum we find the overthrowing innovations that 'pull the rug from under' the established paradigm. To continue with the internal combustion engine; an example of such radical innovation could result from the development of various sorts of hybrids, fuel cell-powered vehicles, or those powered by hydrogen. Radical innovation is thus defined by the contrast with prior technological developments. Truly radical breakthroughs have disequilibrating effects on individual firms, industries, and potentially also on entire economies (Tushman and Anderson 1986). Owing to slow diffusion processes, required complementary innovation and human capital formation, infrastructure, and regulations, the effects of radical breakthroughs can be delayed (Schön 2006a). See Green et al. (1995) and Garcia and Calantone (2002) for a critical discussion of the use of different dichotomies.

[31] Cyert and March 1963; Levinthal and March 1981. Cyert and March (1963) distinguish between "problemistic" search; "search that is stimulated by a problem/…/and is directed toward finding a solution to that problem" (Cyert and March 1963 p. 121) and "slack" search which is search for "innovations that would not be approved in the face of scarcity but have strong sub unit support" (Cyert and March 1963 p. 279). "Problemistic" search is induced by the failure to meet aspired levels of performance.

the firm, of which this concept is a central part, suggests that firms can either search for innovations within the vicinity of existing products, available knowledge, and practices, thus exploiting current resources, or they can move in other directions to explore new knowledge and build new resources.[32] These two search modes are known as local and distant search.[33] This search typology is often taken to underpin innovation outcome. Local search breeds innovations close to a firm's current processes or product offerings while distant search breeds innovation notably different from the present repertory.[34] By definition, innovations in the second category represent major modifications of the structure of the innovating firm's product portfolio. Such innovations include those that expand the technological and/or strategic frontier of the firm (the latter e.g. through unrelated product diversification).

The data explored in this thesis is skewed towards innovations representing major, or significant, modifications of the structure of innovating firms' product portfolios. Hence, the innovations analyzed in this thesis are not representative of the entire spectrum of innovations. When summoned, these innovations are assumed to represent the locus of structural transformation within the manufacturing sector.

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[32] Cyert and March 1963; Nelson and Winter 1982; March 1991; March and Simon 1993.

[33] Another pair of concepts that basically describe the same thing is *exploration* and *exploitation* (March 1991), where the former denotes "search, variation, risk taking, experimentation, discovery, and innovation" (March 1991 p. 71) and the latter "refinement, choice, production, efficiency, selection, implementation, and execution" (ibid). Exploitation aims at "the refinement and extension of existing competencies, technologies and paradigms" (March 1991 p. 85).

[34] The outlook conducive to a major reconfiguration innovation is constrained by a multitude of different factors; bounded rationality (Simon 1955, 1991), routines (Nelson and Winter 1982), traps of organizational learning (Levitt and March 1988; Levinthal and March 1993), limited resources (Penrose 1959; see Pfeffer (2003) for an overview), and the environment (Aldrich and Pfeffer 1976; Pfeffer and Salancik 1978; Hannan and Freeman 1984; Hrebiniak and Joyce 1985; Carroll and Hannan 2000). Accordingly, there is a good deal of empirical evidence of a local search bias in firms in various industries (Helfat 1994; Stuart and Podolny 1996; Martin and Mitchell 1998). It seems that the more distant the innovation is from current products and technologies, the more effective are the constraints. Every innovation is an effort, but the really path breaking variety is compelled to overcome an abundance of obstacles.

1.3 The locus of innovation

This thesis investigates three aspects of innovation output locus: time, firm size, and the distribution of innovations across different industries. Sections 1.3.1 through 1.3.3 will review the literature on each of these aspects. The reviews generate concretely specified versions of the three basic research questions that were formulated at the beginning of the chapter (*when* did firms innovate? *who* were the innovators? and what *kind* of innovations are we referring to?).

1.3.1 When do firms innovate?

The incidence of innovation is an encompassing issue that has been studied on multiple levels of the economy. This literature review will begin from the level of the aggregate economy and work its way down to the individual firm.

Although classical economists such as Adam Smith and John Stuart Mill recognized that new technology was one central driving force of economic growth, it was not until the 1950s that neo-classical descendants started to ponder its peculiar role in greater depth. Nonetheless, following the recognition that technical change was one of the primary sources of economic growth, it was treated as being exogenous to the economic process. [35] The first endogenous growth models appeared in the 1980s.[36] In those models economic growth and technical change is modeled in much the same way; linearly and incrementally growing.[37] Furthermore, innovations in such models are equally novel and important and the effect of innovation upon growth is not subject to any major lags. Recent decades have seen endogenous growth models incorporate features previously not

[35] Kendrick 1956; Solow 1957. See Abramowitz (2003) for a review of the development of growth accounting.

[36] For literature pertaining to some of the first endogenous growth models, see Romer (1986, 1990), Lucas (1988), Grossman and Helpman (1991a), and Aghion and Howitt (1992). For overviews see Verspagen (1992), Griliches (1994), and Solow (2000).

[37] Romer 1986; Lucas 1988

considered by mainstream neoclassical economics. The integration of features such as externalities, increasing returns to scale, and the possibility of monopoly power has accorded these models the epithet *Schumpeterian* growth models, after Joseph Schumpeter.[38]

Schumpeter argues that instability, rather than linearity and incremental accumulation, characterize the capitalist system. A central supposition of his is that the economy evolves through "perennial gale[s] of creative destruction".[39] Creative destruction is defined as a "process of industrial mutation that incessantly revolutionize the economic structure from within, incessantly destroying the old one, incessantly creating a new one".[40] The character of this process is the opposite of the linear process proposed in the early endogenous growth models. A heterodox group of scholars embraces the Schumpeterian legacy and unite in studying technological change and economic growth from an evolutionary point of view.[41] Given the assumption that economic and technological development are interrelated and irregular, a major task taken on by this group of so called evolutionary economists is to pin down the exact character of this relationship.[42] Researchers have exerted themselves diligently towards this end but even today the literature is inconclusive on whether fluctuations in economic growth cause innovation or whether the causal direction runs the opposite

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[38] Verspagen 1992. See Aghion et al. (2013) for an overview. There has been some debate regarding the extent to which the newer endogenous growth models break with the assumptions underlying prior endogenous growth models and additionally to what extent they capture the Schumpeterian legacy; see e.g. Nelson (1994) and Alcouffe and Kuhn (2004).

[39] Schumpeter 1942

[40] Schumpeter 1942 p. 83

[41] Nelson and Winter 1974; Mokyr 1990b; Levinthal 1998; Fagerberg 2003. The ontologies of mainstream neoclassical and evolutionary economists are very different. The latter group rejects not only the idea that the economy and technology will grow in a linear, steady fashion but the very foundations of such ideas: general equilibrium, perfect competition, constant returns to scale, fully rational and utility maximizing individuals etc. See Nelson and Winter (1974) for one of the first accounts where the two perspectives are displayed in opposition to each other. Furthermore, see Nelson and Winter (1982) for the first major work within the area of evolutionary economics. See also Dopfer (2001, 2005) for overviews of the evolutionary research agenda.

[42] See Silverberg (2002).

way. The contrasting positions are typically denoted demand-pull and supply-push.[43] A related line of research centers on the temporal pattern of the economic growth and technological change nexus. Such patterns have been studied in both long and short time perspectives. The former has been a preoccupation of scholars engaging in the study of so-called long waves. A long wave theoretically spans from over 40 to 60 years and encompasses extended periods of economic prosperity as well as decline. Typically, a long wave contains one protracted period of prosperity and one of decline, although both may include temporary upward and downward swings of the business cycle. Inspired by Schumpeter, the majority of the long-wave scholars argue, that significant innovation is a phenomenon restricted to periods of decline and depression.[44] Others assign the extensive occurrence of significant innovations to upswings.[45]

Belonging to the former group of long-wave scholars, Mensch (1979) argues that economic stagnation is caused by the depletion of the economic growth potential in "predominant technologies" and a failure to bring about

[43] The debate between the two positions is long-standing. In his early work, Schumpeter adopts a supply push view when arguing that entrepreneurs seize ever-abundant opportunities and set in motion waves of economic growth (Schumpeter 1939; Coombs et al 1987 p. 175ff). In later contributions, Schumpeter describes entrepreneurial activity and innovation as an endogenous phenomenon (Schumpeter 1942). Kondratiev (1935), one of the first to argue that the economy is governed by long waves, suggests likewise that innovation is endogenous (Rosenberg and Frischtak 1994 p. 65). Later contributions are found at both ends of the spectrum. Phillips (1966), Rosenberg (1974), Dosi (1982, 1988), and Jovanovich and Lach (1997) suggest that there is a unidirectional link from scientific and technological progress to economic growth. Conversely, Schmookler (1966) argues that changes in demand are the central driving forces of innovation. Numerous contributions have proved Schmookler's demand-pull hypothesis correct (see e.g. Myers and Marquis 1969; Langrish et al 1972; Brouwer and Kleinknecht 1999b) and incorrect (see e.g. Scherer 1982; Kleinknecht and Verspagen 1990). Increasingly, the literature has come to consider innovation as being caused by a mix of the supply of science and technology, demand, and other economic factors (Rothwell 1992). In this vein, Mowery and Rosenberg state that "[b]oth the underlying , evolving knowledge base of science and technology, as well as the structure of market demand, play central roles in innovation in an interactive fashion, and neglect of either is bound to lead to faulty conclusions and policies" (Mowery and Rosenberg 1982 p. 195). Several of the more famous innovation models draw on multi-directional causation (Kline 1985; Kline and Rosenberg 1986; Pinch and Bijker 1987).

[44] See for example Mensch (1979), Freeman et al. (1982), Freeman and Louçã (2001), Perez (2002), see also Schön (1998, 2006a, and ch. 3 in this thesis)

[45] Van Duijn 1981, 1983

piecemeal new innovations.[46] This "stalemate of technology" comes to an end when "basic innovations, which establish new branches of industry, and radical improvement innovations, which rejuvenate existing branches" present themselves.[47] In Mensch's view, a protracted depression is thus a maieutic period during which economies undergo profound restructuring.

Other scholars discuss the management rationale of investing in innovation in upswings or downswings.[48] In doing so, both the time perspective and the level of analysis are changed. The typical argument for a pro cyclical launch of innovations based on a proposed management rationale suggests that innovations will be launched in upswings because the market is in a stronger position to absorb a new product in times of expansion. Hence, a firm would want to put their new product on the market when such windows of opportunity are open. Furthermore, since profits accruing to first movers are temporary, commercializing during or at the beginning of an upturn may maximize such rents.[49] The majority of arguments justifying a short term *counter* cyclical relationship between the business cycle and innovation center on R&D investments rather than innovation output.[50] The quintessence of such arguments is that firms will invest in R&D in downturns because the opportunity cost of new product development is lower when profits from sales are already foregone.[51]

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[46] Mensch 1979 p. 5

[47] Mensch 1979 p. xvii

[48] Kleinknecht 1981

[49] Shleifer 1986; Francois and Lloyd Ellis 2003. Geroski and Walters (1995) is the most frequently cited empirical account of a short term pro cyclical relationship between innovation and the business cycle.

[50] The relationship between innovation launches and the business cycle on the one hand and R&D investments and the business cycle on the other is likely to exhibit different characteristics and a thorough comparison between pro and counter cyclical arguments is therefore problematic. In addition, several contributions find no relationship at all between economic fluctuations and innovation activities (Saint-Paul 1993; McGahan and Silverman 2001).

[51] Aghion and Saint-Paul 1998. In an upturn, there exists the potential alternative of investing in ramping up production. The opposite argument highlights the poor availability of funds in downturns and suggests that there will be cuts in R&D budgets when cash flows decrease (Himmelberg and Petersen 1994; Brockhoff and Pearson 1998). However, the credit-constraints explanation has been questioned on the basis of findings that show that

Much like the evolution of the aggregate economy, the development of industries has been discussed in terms the extent to which the pattern appears continuous or cyclical.[52] The focal points of the so called industry life cycle literature refer to the volume and character of innovation and changes in the firm population size, rather than the industrial relationship with business cycles or long-term economic trends.[53] The typical assumption is that the number of innovations, their character, and the number and character of the firms inhabiting an industry are subject to change as an industry matures. Klepper (1997) describes the different stages of an industry life cycle in the following way:

> "In the initial, exploratory or embryonic stage, market volume is low, uncertainty is high, the product design is primitive, and unspecialized machinery is used to manufacture the product. Many firms enter and competition based on product innovation is intense. In the second, intermediate or growth stage, output growth is high, the design of the product begins to stabilize, product innovation declines, and the production process becomes more refined as specialized machinery is substituted for labor. Entry slows and a shakeout of producers occurs. Stage three, the mature stage, corresponds to a mature market. Output growth slows, entry declines further, market shares stabilize, innovations are less significant, and management, marketing, and manufacturing techniques become more refined."[54]

With regard to the issue of whether truly novel innovations appear continuously or discontinuously, the industry life cycle perspective clearly

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firms invest in other costly activities (such as reorganization, training and machine upgrading) counter-cyclically (Nickell et al. 2001; Francois and Lloyd-Ellis 2003). It has also been shown that firms that are relatively unconstrained financially will nonetheless focus their R&D investments in upturns (Barlevy 2005). Empirical evidence of pro-cyclical R&D spending includes Griliches (1990), Fatas (2000), and Comin and Gertler (2006).

[52] Gort and Klepper 1982; Klepper and Graddy 1990; Klepper and Miller 1995; Klepper 1996, 1997. The life of products has been subject to the same analytical framework (see e.g. Utterback and Abernathy 1975).

[53] Audretsch and Feldman 1996

[54] Klepper 1997 p. 148

subscribes to the latter position. Another branch of the industry-level literature concerns the situation where a stable industry faces disruptive change by means of radical innovation and/or innovative entry.[55] New technology may shred the competitive advantage of incumbents, make current competencies obsolete, lead to prolonged periods of performance downturn, and ultimately, if no action is taken, to failure.[56] Such discontinuous events spark periods of intense technological competition and a variety of venturous innovations are developed as firms strive for dominance. The uncertainty that surrounds future use and applications of the new technology gives rise to what Freeman calls the "bicycle syndrome"; firms go 'all in' on innovation to ensure not being left behind by faster-pedaling competitors.[57]

Plentiful accounts observe that industries and firms oscillate between periods of relative stability and periods during which central characteristics (e.g. market structure and product portfolios) undergo profound change.[58] Other accounts argue that firms and industries change in a continuous fashion through minor increments and adjustments.[59] The two views are reconciled

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[55] Tushman and Anderson 1986; Utterback and Kim 1986; Bower and Christensen 1995; Christensen 1997

[56] Abernathy and Clark 1985; Tushman and Anderson 1986; Hambrick and D'Aveni 1988; Henderson and Clark 1990; Rosenbloom and Christensen 1994; Bower and Christensen 1995; Christensen 1997. Reorientations are not impossible. With high levels of absorptive capacity (Cohen and Levinthal 1990) and dynamic capabilities (Teece et al. 1997) established firms may manage to catch the wave of creative destruction rather than being drowned by it (Tripsas 1997; Ferrier et al. 1999; Ahuja and Lampert 2001; Storm 2007). Several scholars investigate the ways firms try to manipulate and control their environment. For an overview of such contributions see Aldrich (2008). Overthrowing technological change as discussed by industry life cycle scholars is but one of many factors that affect the environment in which a firm exists. Relative prices, institutions, and other exogenous factors may change so as to redefine the task environment and put firms in a position where they have to face changes that they are not capable of influencing but rather have to adapt to. See footnote nr 24.

[57] Freeman 1982

[58] Thompson 1967; Abernathy and Utterback 1978; Miller and Friesen 1980, 1982, 1984; Tushman and Romanelli 1985; Tushman and Anderson 1986; Mokyr 1990b; Romanelli and Tushman 1994; Utterback 1994; Klepper 1996; Tushman and O'Reilly 1996; Weick and Quinn 1999; Siggelkow and Levinthal 2003; O'Reilly and Tushman 2008; Mintzberg et al. 2009 p. 318ff.

[59] Quinn 1980a, 1980b: Donaldson 1996, ch. 6; Brown and Eisenhardt 1997; Tsoukas and Chia 2002

by the suggestion that firms change both continuously and discontinuously, but do so alternately.[60] This argument poses that most of the time an organization can be described in terms of some kind of stable configuration of its characteristics: for a distinguishable period of time, it adopts a particular form of structure matched to a particular type of context which causes it to engage in particular behaviors that give rise to a particular set of strategies. These periods of stability are occasionally interrupted by processes of profound transformation -a quantum leap to another configuration.

The practical difficulties in combining both gradual and episodic change are discussed in William J. Abernathy's influential 1978 article '*The productivity dilemma: Roadblock to innovation in the automobile industry'*. Abernathy's point of departure is the typical circumstance where firms are endowed with only a limited number of resources consequently implying that every activity is forced to compete for means of different kinds. Hence, too much investment in incremental change will be made at the expense of investment in major innovation.[61] Firms that manage to juggle both these modes; to integrate and improve current knowledge while at the same time maintain sufficient capacity to explore new turf will be more viable in the long term.[62] Firms that manage to walk this tightrope have been called *ambidextrous*.[63] While ambidexterity is a desirable characteristic to aspire to, contributions from a wide variety of research traditions suggest that influential mechanisms in organizational life will work so as to crowd out exploration, the underpinning of all major structural modifications and updates.[64]

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[60] Mintzberg et al. 2009

[61] Activities that attract capital also attract the cognitive energy of the employees, and commitments to the chosen course of action may escalate (Staw 1976). The organizational learning perspective suggests that commitment may be subject to centrifugal forces if feedbacks from action are positive (Levitt and March 1988; Levinthal and March 1993). Abernathy (1978) argued that firms which fail to cut back on means devoted to efficiency would be less capable of developing innovations in accordance with the universally applicable logic that 'one will master only what one practices' (see also Cole and Matsumiya 2007).

[62] Teece et al. 1997

[63] O'Reilly and Tushman 2008. See also Eliasson (1996).

[64] A growing literature engages in understanding how firms can master this act of balance (see Adler et al. (2009) for a recent overview of the field).

Increased rigidity which is linked to firm age and size (an issue discussed in section 1.3.2) is often referred to as one such mechanism.[65]

The threat of decline and failure is argued to be a powerful incentive to modify the structure of a firm.[66] Similarly, organizational learning scholars suggest that firms will search and innovate when they fail to meet aspired targets.[67] The decision arrived at which determines whether to persist with current products, activities, and strategies or whether to pursue a new path will itself be influenced by an assessment of the extent to which goals are achieved.[68] This line of reasoning suggests that search and innovation echo dissatisfaction with performance. Conversely, when satisfaction increases the amount of search will by contrast decrease.[69] A firm with a full order-book and a positive cash-flow is, according to this view, less likely to reconsider their current products and strategies than is a firm with en empty order-book and a petering cash-flow. Hence, failure or the threat thereof induces innovation.

This literature review has discussed the timing of innovation with regard to extended periods of relative decline and prosperity and in some regard the relationship between innovation and short term swings of the business cycle. The narrative proceeded to revisit the literature relating to motivations for spurring innovation and various mechanisms of innovation within industries and individual firms. The path followed especially regarded innovations representing major modifications of product portfolios as well as the relationships between such innovations and firm performance. Given the inconclusive literature on the exact relationship between economic performance and innovation, the following question is posed in order to shed light on the association between innovation and long term fluctuations in Swedish economic growth:

RQ1: Was there a key period of innovation and if so, when did it occur?

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[65] Hannan and Freeman 1977, 1984, 1989; Leonard-Barton 1992

[66] Hirschman 1970

[67] Cyert and March 1963; Levinthal and March 1981; March and Simon 1993

[68] March and Olsen 1976; Levitt and March 1988

[69] March and Simon 1993 p. 194

1.3.2 Firm size and innovation

There are several ways to differentiate firms: ownership, organizational structure, resources etc. Firm size, measured as the number of employees, is the more frequently used way to distinguish between firms when it comes to the propensity to innovate. The debate about whether firms of all sizes are equally potential innovators dates (at least) back to Schumpeter who in his early work suggested that entrepreneurs are the primary developers of significant innovations, the so-called Schumpeter Mark I standpoint.[70] Later in his career Schumpeter came to revise his position and argued that such innovation takes place primarily within large firms, a standpoint consequently called Schumpeter Mark II.[71] Ever since, firm size has been one of the central topics on the innovation research agenda.[72] Indeed, such a lengthy debate is indicative of inconclusive results (and importance).[73]

The large firm was long held as being the sovereign way of organizing production and innovation. In the 1950s and 1960s work by John Kenneth Galbraith and Alfred Chandler suggested that there is an intrinsic link between the mass producing and vertically integrated large firms and changes of consumption patterns; such firms were the primary engines of growth as the modern capitalist economy evolved during the 20th centuries.[74] The key to this contention is economies of scale and efficiency. Small firms were considered incapable of competing in the new capitalist regime as they could not produce the same volumes as large firms. Hence, the large firm advantage pertains to resources. Large firms are not only capable of mass producing goods, they are also capable of financing expensive innovation projects. Small or start-up firms may have to turn to external sources of capital and credit markets whereas large firms are better equipped to assemble financial resources internally. In addition, large

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[70] Schumpeter 1934. Entrepreneur here refers to activity by free standing individuals, startup firms, and small firms.

[71] Schumpeter 1942

[72] See e.g. Cohen and Klepper (1996).

[73] Tether 1998. Ahuja et al. (2008) notes that ten years later, the debate is still not settled.

[74] Galbraith 1952, 1967; Chandler 1962. See also Chandler (1990).

diversified firms generally market a broader range of products over which they can spread the costs of innovation and to which they can apply innovative technology.[75] At the point in time of commercialization, large firms may be in a superior position in terms of accumulated investment in public relations and may as a result diffuse their innovations with more ease than small firms with less outreach. Furthermore, the incentive to engage in innovation in the first place may increase if markets can be envisioned or are already established.

However, the multidivisional large firm structure described for example by Chandler in his 1962 book may also be considered an obstacle to innovation. Prior success and uncertainties regarding the profit outlook of a new innovation may make large firms hesitant to forego the opportunity to step up production of current, successful products.[76] In addition, nascent inventions or ideas may be considered too insignificant to survive, especially if they upset current activities and/or are distant to those. In addition, the complex structure of large firms is likely to make them more bureaucratic and less flexible than small firms. Vested interests and rigid organizational structures may obstruct change and contribute to high levels of inertia.[77] Tushman and Romanelli (1985) have described organizational inertia in the following way:

> "As webs of interdependent relationships with buyers, suppliers, and financial backers strengthen and as commitments to internal participants and external constituencies are elaborated into institutionalized patterns of culture, norms, and ideologies, the organization develops inertia, a resistance to all but incremental change".[78]

Inertia has been argued to result from mechanisms of organizational learning.[79] Largely, organizational learning regards processes through which

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[75] Cohen and Klepper 1996

[76] See the discussion about the productivity dilemma in the previous section.

[77] Hannan and Freeman 1977, 1984, 1989; Leonard-Barton 1992; Dougherty and Hardy 1996

[78] Tushman and Romanelli 1985 p. 177

[79] See Argyris and Schön (1978) and Levitt and March (1988) for introductions to the organizational learning literature.

firms learn about the environment and the firm-environment interface (i.e. its fit).[80] One of the primary sources of learning is experience. When firms articulate strategy and take action, they draw on what they have learnt in the past.[81] However, the recipes of past and future success may differ and so organizational learning scholars have argued that experience may be a poor guide to action in turbulent environments.[82] Drawing on experience may be particularly cavalier when the pool of prior events from which to learn is limited.[83] On the other hand, a growing volume of literature suggests that innovation is persistent on the level of the individual firm.[84] Cumulativeness suggests that prior success in innovation breeds future success and that a positive track record is highly beneficial rather than inhibitory.

The 1980s saw the attention of the debate about innovation and firm size turn towards the role played by small firms.[85] This increased attention paid to small firms reflected an ongoing structural shift from large to small firm dominance in the industrial firm population, a shift that occurred in virtually all leading industrial nations.[86] Two overarching explanations of the shift have been proposed.[87] The first pertains to a fundamentally changed

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[80] Fiol and Lyles 1985; Levitt and March 1988; Argyris 1993

[81] Levitt and March 1988; Levinthal and March 1993; March 1994

[82] Over-reliance on prior positive experiences has been described as a success or competency trap (Levinthal and March 1993; Levitt and March 1988). See Argote and Miron-Spektor (2011) for a review and discussion of the literature on organizational learning and experience.

[83] March et al. 1991; Lampel et al. 2009

[84] Malerba et al. 1997; Roper and Hewitt-Dundas 2008; Peters 2009; Raymond et al. 2010; Clausen et al. 2011; Clausen and Phojola 2013; Triguero and Corcoles 2013. Cumulativeness of innovation and R&D in the aggregate economy is a central assumption of modern endogenous growth models. See Jones (2005) for a review of this literature.

[85] Birch 1979; Brock and Evans 1986; 1989; Acs and Audretsch 1988; 1989; 1990; Acs 1992; Audretsch 1995. Birch (1979) was an early writer on the importance of small firms in the job creation process. An indication of growing interest in small firms is reflected in the large number of journals, addressing the role of small firms exclusively, that were founded during the 1980s. Examples of journals include *International Small Business Journal*, *Journal of Small Business*, and *Small Business Economics*.

[86] Loveman and Sengenberger 1991; Carlsson 1992a; 1999; Acs and Audretsch 1993a; Audretsch and Thurik 2001

[87] Carlsson 1992a

world economy. The major changes regard intensified global competition with associated growing uncertainty and market fragmentation. The other explanation relates to technological change and points especially at the penetration of flexible automation systems. These systems, as well as the reduction of set-up time and the enabling of flexible specialization gave firms in the leading industrial nations a better chance of confidently meeting increased competition from low wage countries. The increase in appreciation of and focus on flexibility downplayed the outright benefits of mass production.[88] Other related trends that generated interest in small firms include decentralization and vertical disintegration (i.e. firms concentrate their activities in a few core areas).[89]

The theoretical argument in favor of Schumpeter Mark I (according to which entrepreneurs, startup firms, and small firms comprise the predominant innovators) lies in the flexibility with which small organizations can operate. Bureaucracy and rigidity are comparatively absent and thus barriers to reorientation and timely decision-making are relatively smaller.[90] Few hierarchical levels provide employees with more influence which results in motivational commitment.[91] Motivation in small firms may be further enhanced if roles are intertwined as they are when managers are also in ownership positions.[92] While according to Oliver Williamson large firms can be characterized by "low-powered incentives" and a *low* covariance between employee compensation and performance, small firms by comparison exhibit *high* covariance.[93]

While the small firm enjoys behavioral flexibility, it suffers from resource constraints.[94] Neither large nor small firms possess unlimited resources, but

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[88] Eliasson 1990a p. 31-3

[89] Loveman and Sengenberg 1991; Crafts 2006

[90] Scherer 1980; Teece 1996

[91] Ahuja et al. 2008

[92] Nootebom 1994

[93] Williamson 1985 p. 153

[94] Freel 2000. Indeed, the flipside of being few is resource constraints. Fewer people equal fewer brains, a significant amount of knowledge may be tacit and a small firm may thus be

resource constraints may be a barrier to innovation in small firms in particular.[95] Freel (2000) summarizes some of the more important resource constraints:" [a] lack of technically qualified labour; poor use of external information and expertise; difficulty in attracting/securing finance and relating inability to spread risk; unsuitability of original management beyond initial prescription; and, high cost of regulatory compliance".[96] In particular, the literature has focused on financial constraints. While the firm is endowed with limited internal funds, the possibility of attracting or borrowing external capital is potentially hampered by information asymmetry and potential moral hazard issues.[97] As a consequence, properly working private equity and debt markets are considered crucial for the ability of small firms to allocate money for innovation.[98] This remark has been made in particular with regard to entrepreneurial ventures (i.e. startup firms).[99] Access to external capital has been demonstrated as critical for startup ventures, while liabilities of 'newness' and 'smallness' have been highlighted as hindrances in accessing such capital.[100] Other institutional factors suggested to influence startup activity include taxes and market

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more vulnerable to the discontinuity of management and staff (Nootebom 1994). Persistence in innovation may therefore be a bigger challenge in small firms than in large firms.

[95] Penrose 1959; Freel 2000

[96] Freel 2000 p. 61

[97] Storey 1994; Storey and Tether 1998; Freel 2000. Gertler and Gilchrist (1994) show that in cases of recession small firms are relatively worse hit than large firms when it comes to external lending possibilities.

[98] European Commission 2012. See Berger and Udell (1998, 2006) for an overview of the field of small business finance research.

[99] Capital constraints have been discussed not only in terms of external capital but also in terms of private financial capital possessed by prospective entrepreneurs and the extent that this predicts the likelihood of the establishment of a firm and additionally, the success of started firms. See for example Evans and Jovanovic (1989), Holtz-Eakin et al. (1994), Hurst and Lusardi (2004), and Aldrich and Rueff (2006).

[100] Hannan and Freeman 1989; Hellman and Puri 2000, 2002. As a contrast, Stouder and Kirchhoff (2004) argue that external capital is overrated as a source of entrepreneurial funding.

regulation.[101] Taxes are primarily discussed in terms of to what extent they encourage self-employment or not.[102] The literature on market regulation, competitiveness, small business, and entrepreneurship evolved in the context of slow European growth during the 1980s and the political and economic liberalization taking place in Europe and the U.S. during the 1980s and 1990s.[103] During this period, the academic and political debates very much fed back on each other and a standard view that small business and entrepreneurship (taken together) were the saviors of competitiveness and economic growth emerged.[104] To realize this potential salvation, regulations had to be abolished.

There exists a large volume of literature on the relationship between the novelty of innovations and firm size. The stylized view in this literature suggests that large firms are more likely to develop incremental innovations while small firms, and startups in particular, are more capable of developing radical innovations.[105] This relative advantage stems from the flexibility and the relative absence of hierarchies in small firms. Much of this literature is based on case studies on individual products and firms (of which the majority are based in the U.S.) sampled by means other than formal statistical sampling.[106]

There is of course not only large and small firms in a firm population, but also a group of medium-sized firms.[107] The literature surprisingly lacks a useful empirical analysis of the role of innovation in medium-sized firms.

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[101] See for example Ardagna and Lusardi (2010) and Nyström (2010).

[102] Bruce and Mohsin 2006; Hansson 2012. See the latter for a thorough review of recent empirical contributions.

[103] Galli and Pelkmans 2000. See Audretsch (2007) for a discussion of the emergence of entrepreneurship policy.

[104] E.g. UNICE 1995; European Commission 2012. See Galli and Pelkmans (2000) for an overview of reports and documents expressing this shared view.

[105] See e.g. Henderson and Clark (1990), Ghemawat (1991), Henderson (1993), Rosenbloom and Christiansen (1994), Utterback (1994).

[106] See Chandy and Tellis (2000) for an overview of contributions in this field.

[107] See news article in The Economist (2012).

Such firms are either not studied or are lumped together with small firms under the SME label (small and medium-sized enterprises).[108]

This review of the literature on firm size and innovation has addressed several types of factors likely to influence the innovation propensity of firms of different sizes; internal factors (e.g. resources), institutional factors (e.g. capital markets), and international factors (e.g. globalization and market fragmentation). The ambition of the literature review has been to identify innovation conditions and how those typically vary with firm size. The standard narrative suggests that small firms are becoming increasingly important. The review shall serve as a background to the investigation of changes in the structural composition of firms of different sizes within the population of innovators explored in this thesis. Based on this literature review the following research question is asked:

RQ2: Did firms of all sizes innovate to the same extent during the period?

1.3.3 Structural change and the manufacturing sector

Structural change is a classic topic in economic history. As already noted, Nobel laureate Simon Kuznets has suggested that a high rate of economic growth is associated with a high rate of shift of production structures.[109] Indeed, the modern era has been characterized by high average economic growth rates and fundamental shifts of the kind just mentioned. The first major shift was initiated with industrialization and regards the relative decline of the agricultural sector, both in terms of employment and as a share of GDP, and the parallel growth of the industrial manufacturing sector.[110] By the 1970s manufacturing employment was larger than that in agriculture in the majority of Western European countries.[111] The next great

[108] See news article by White (2013) in The Daily Telegraph. While accounts treating medium-sized firms are few, there is a sizeable literature on the growth of small firms. See Davidsson et al. (2005) for a review of this literature.

[109] Kuznets 1971

[110] Schön et al. 2010

[111] Schön et al. 2010

shift; from manufacturing to services, took off in the 1970s. By the year 2000, a majority of the Western European work force was employed in the service sector.[112] Similarly, the service sector overtook manufacturing with regard to share of nominal GDP.[113] The structural shift has resulted in designations of the contemporary period as the *new economy*, a *service economy*, and a *postindustrial society*.[114]

In terms of real production however, it has been shown that in countries such as Germany, the U.S., the U. K., the Netherlands, Japan, Sweden, Italy, and France, the real growth of the service sector was only modest.[115] Real production numbers thus suggest that reports of the death of industrial society are greatly exaggerated.[116] As a pendant to the discussion of whether the current economy is dominated by manufacturing or services several authors argue that the division between the two sectors is outdated. In this vein Schön et al. (2010) state that the "deindustrialization in the sense of lower employment in the manufacturing sector is partly due to the new symbiosis between industry and services. Some of the service sector's rapid growth at the expense of the manufacturing sector since the 1970s is a statistical optical illusion".[117] The statistical illusion is in part caused by vertical disintegration and the related growth of the business service sector.[118]

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[112] D'Agostino et al. 2006; OECD 2000

[113] For Sweden, see Schön and Krantz (2012).

[114] Bell 1973; Gershuny 1978; Alexander 1983; Gershuny and Miles 1983

[115] Henriques and Kander 2010. The sector grew modestly in Germany, the U. S., the U. K., and Japan whereas the sector grew negligibly or even contracted in Italy, the Netherlands, Sweden, and France (Henriques and Kander 2010). Henriques and Kander (2010) and Kander (2005) attribute the different pictures given by nominal and fixed prices to an incidence of Baumol's cost disease (Baumol and Bowen 1966; Baumol 2012). Baumol's argumentation suggests that since there is less scope for productivity increase in the service sector, prices must consequently be raised to enable wage increase.

[116] Kander 2005; Lagerqvist 2012

[117] Schön et al. 2010 p. 397

[118] Pousette 1985; Wood 1991; Carlsson 1998; Eliasson 2002 p. 58; Lundquist et al. 2008. Lindh (2014) claims that the interaction between the manufacturing and service sectors is still a poorly investigated topic.

Another phenomenon blurring the boundaries between the manufacturing and the service sector is the process of 'servitization'.[119] This label/concept refers to the growing share of services in the product portfolios of manufacturing firms.[120] Differentiation through process-oriented, customized service offerings enable higher margins compared to standardized products, and has visibly enhanced competitiveness, firm value, and helped to reinforce a market position.[121]

The growing share of services in total production is only one important structural change. Fundamental intra-sectorial structural change in the production of manufactured goods has also occurred since the 1970s. This profound change originates from the invention and diffusion of fast and cheap microelectronic components. The launch of Intel's first microprocessor (Intel 4004) in 1971, and the revolutionary development of computers which followed from approximately the same time, heralded a new era.[122] The pervading consequences of the subsequent penetration of microelectronics and computers have been described as an industrial revolution.[123] The effects of microelectronics are thus regarded as equivalent to those of steam power (the first industrial revolution) and electricity (the

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[119] Baines et al. 2009

[120] Davies 2004; Henkel et al. 2004; Howells 2004; Neu and Brown 2005; Kowalkowski 2006; Penttinen and Palmer 2007; Gebauer et al. 2010. See Pousette and Lindberg (1986), Pousette (1987), Braunerhjelm (1992), Berggren et al. (2005), Fölster and Johansson Grahn (2005) for empirical accounts of the role of service in the Swedish manufacturing sector.

[121] Levitt 1976; 1983; Mathieu 2001; Olivia and Kallenberg 2003; De Toni and Tonchia 2004; Fang et al. 2008; Gebauer et al. 2011. Although accounts report of a growing importance of providing services to complement product offerings (for instance, through service packages) this is not a new phenomenon. Beginning in the 1920s and 1930s for example, Atlas Copco formalized a strategy aiming at establishing close relationships with customers. The strategy was refined, firmly established and functioning when, during the Second World War, Atlas Copco developed a lightweight and efficient rock drill which had been equipped with cutting edge drill bits from Sandvik. The new rock drill was successfully sold as a method rather than a traditional product and Atlas Copco developed ambitious sales and service departments to cater for the needs of customers (Atlas Copco 2013). Kowalkowski (2006) points at the growing importance of services and provides four comprehensive case studies of service offerings in well-established Swedish firms (ITT Flygt, BT Europe, Saab Aerosystems, and Electrolux Laundry Systems).

[122] This dating of the microelectronic era follows that in Jovanovic and Rousseau (2005).

[123] Greenwood 1997; Castells 1998; Freeman and Louça 2001 (ch. 9); Perez 2002

second industrial revolution). The profound societal effects of microelectronics (and steam power and electricity for that matter) result from the general applicability of the technology.

Technologies with a wide spectrum of uses have been labelled *general purpose technologies* (henceforth GPT).[124] Three features have been suggested to capture the character of a GPT. First, *pervasiveness* regards the scope for applications in downstream sectors. Second, *technological dynamism* refers to the technology's "potential to support continuous innovational efforts and learning, which allows for large increases in the efficiency in the GPT over time".[125] Third, *innovational complementarities* exist between user sectors and the GPT. These characteristics make GPTs powerful engines of economic growth.[126] Helpman and Trajtenberg (1998) summarize the mechanisms by which a GPT spurs growth:

> "As a better GPT becomes available, it gets adopted by an increasing number of user sectors and it fosters complementary advances that raise the attractiveness of its adoption. For both reasons the demand for the GPT increases, inducing further technical progress in the GPTs, which prompts in turn a new round of advances downstream, and so forth. As the use of a GPT spreads through the economy, its effects become significant at the aggregate level, thus affecting overall growth".[127]

An important dimension of this development is a decrease in relative price.

Given the potential of microelectronics to revolutionize all sectors of the economy the dismal European and U.S. productivity growth of the 1980s was a puzzle to growth accountants. Robert Solow famously stated that "you can see the computer age everywhere but in the productivity statistics".[128] Several explanations of the so called Solow paradox have been proposed of

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[124] Bresnahan and Trajtenberg 1995. See Bresnahan (2010) for a recent review of this literature.

[125] Bresnahan and Trajtenberg 1995; Lipsey et al. 1998 p. 16

[126] David 1990; Bresnahan and Trajtenberg 1995; Helpman and Trajtenberg 1998

[127] Helpman and Trajtenberg 1998 p. 55

[128] Solow 1987

which unrealistic expectations has become the most accepted.[129] Too much was simply expected too soon.[130] The recovery of productivity growth rates in the second half of the 1990s dispelled concerns and have generally been interpreted as a realization of the potential embodied in microelectronics in general and information and communication technologies (henceforth ICT) in particular.[131] The delay of effects on growth is typically referred to time consuming processes of learning, diffusion, and the development of complementary innovations and enabling infrastructure.[132] One example is the Internet. The World Wide Web infrastructure was indeed complementary and enabling. The internet took off commercially in 1994 when Mosaic Corporation launched the internet search engine that was later to be known as Netscape. While in the early 1990s the Internet was something very few people with a particular interest in this technological niche were even aware of, at the end of the same decade it was available in class rooms throughout much of the OECD world.

This literature review has addressed the key changes in the character of the manufacturing sector: fewer employees but sustained, growing, or an only slightly decreasing growth rate of real production, trends of vertical disintegration, the increasing importance of business service firms and services accompanying products, and the advent and penetration of microelectronics. Developments concerning employees and production are background factors that will be dealt with when addressing research question one, whereas research question number three deals with changes in the structural composition of innovation output. This latter question investigates whether or not there was a considerable change in the structure

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[129] Crafts 2002. See Triplett (1999) for a review of different explanations.

[130] Jovanovic and Rousseau 2005. Helpman and Trajtenberg (1998 p. 56) identify two distinctive phases in the relationship between a GPT and various growth parameters: "[d]uring the first phase, output and productivity experience negative growth, the real wage rate stagnates, and the share of profits in GDP declines. The benefits from a more advanced GPT manifest themselves during the second phase, after enough complementary inputs have been developed for it. During this later phase there is a spell of growth, with rising output, real wages, and profits".

[131] See for example Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Verspagen (2002).

[132] See Hall (2005) and Bresnahan (2010) for reviews of this literature.

of innovation output towards the microelectronic-related innovations which were taking place during the period. The question is specified as:

RQ3: Was there an observable key period of change in the structural composition of innovation output and if so, when did it take place?

1.4 Limitations

This thesis depicts and analyzes quantitative and qualitative changes in the Swedish manufacturing sector's total innovation output for the period 1970-2007. Additionally, it investigates whether changes in certain quantitative and qualitative aspects of innovation output are associated with extended periods of relative prosperity and decline. It does not engage in estimations of the contribution of domestic manufacturing innovation output to GDP or the mapping of causality, i.e. the extent to which changes in innovation output influence the economic growth rate or to which protracted periods of relative prosperity and decline influence the propensity to engage in innovation activity or the volume of innovation output.

Natural limitations are set by the case. Sweden is a small open economy on the outskirts of Europe. Any ambition to generalize the findings of this thesis should take the peculiarities of Swedish development, its policies, and institutions into account. Other limitations are set by the data. The data is limited to the innovation output of the manufacturing sector and the thesis hence omits other important sectors (i.e. services). The observed innovations have all qualified for review in trade journals. Given that such journals have the ambition to report notable technological developments rather than piecemeal improvements, there is a significance bias in the data. The use of this particular data to answer the questions posed in the thesis is justified by the assumption that significant innovations capture profound industrial transformation of local origin to a larger extent than incremental innovations. The majority of the innovations in the dataset are observed close in time to the date of their commercialization.[133] We are thus

[133] Chapter four is devoted to careful description and discussion of the data.

uninformed about their eventual economic and/or structural impact. Certain innovations are easier to detect than others. Service and system innovations originating in the manufacturing sector are intangible and often customized to such an extent that makes it difficult to assess their degree of novelty. To some extent, this remark also applies to ICT innovations as they are often embodied in a "host product". Section 1.3.3 reported on the growing importance of both service and ICT innovations. Regrettably, the data may not reflect this development to its full extent. However, it is assumed that the data captures the truly significant developments in these innovation varieties.

1.5 The remainder of the thesis

Chapter two provides a more complete history of economic and industrial development in Sweden during the 20th century, with emphasis placed on the period 1970-2007. The chapter closes with a sub-periodization of this period. Chapter three explores the received standard analyses of Swedish economic performance and industrial transformation during the same period. The chapter focuses on the two (to a large degree) opposing views surrounding the association between performance and transformation. The empirical chapters will return to the analyses reviewed in chapter three in an attempt to triangulate the subject matter of this thesis. Chapter four introduces and discusses the newly compiled database that is explored in the thesis. Chapter five, six, and seven comprise the empirical chapters of the thesis and they address research questions one, two, and three respectively.

Table 1.1 Research questions

RQ#	Research question	Chapter
1	Was there a key period of innovation and if so, when did it occur?	5. The temporal pattern of innovation
2	Did firms of all sizes innovate to the same extent during the period?	6. The innovating firms
3	Was there an observable key period of change in structural composition of innovation output and if so, when did it take place?	7. The structural composition of innovation output

Chapter five opens the 'black box' of Swedish innovation between 1970 and 2007 by exploring and discussing the temporal pattern of innovation against the backdrop of the development of the aggregate economy and specific aspects of change in the manufacturing sector. Additionally, chapter five studies the novelty of the innovations from the perspective of the world market as well as from that of the individual firm.

Chapter six is a study of the size and character of the innovating firms. The chapter opens with an exploration of changes in the distribution of innovations across the firm-size spectrum. In the second part of the chapter, the novelty of innovations commercialized by small, medium-sized, and large firms are analyzed. In the final part of the chapter, innovator concentration and innovation persistence are explored in turn.

Chapter seven addresses changes in the structural composition of total innovation output and changes in both the number and character of innovations in the output of individual industries. Particular attention is paid to the technological change instigated by the microelectronic revolution. Moreover, chapter seven provides 'close-ups' on seven industries that have seen significant positive or negative change during the period studied in this thesis.

Chapter eight summarizes and ties all findings together by attempting a synthesizing analytical triangulation of the process of industrial transformation in Sweden between 1970 and 2007, based on the analyses reviewed in chapter three and the findings presented in the thesis. The thesis is concluded by the highlighting of some potential directions for future research.

2. Economic and industrial development in modern Sweden

This chapter outlines the historical background of the subject matter investigated in this thesis. It opens with a brief international comparison with Swedish economic performance during the twentieth century up until 2007. Thereafter it proceeds to summarize the main features of economic development in Sweden and those of the manufacturing sector in particular, with a deliberate focus on the last forty years. The end of the chapter presents the periodization that will be used throughout the thesis.

2.1 Sweden's relative economic performance

Between 1870 and 1970 Sweden transformed in such a dramatic manner that it was propelled from the low category of comparative substandard performance to a leading position in terms of economic and industrial development among the nations of the world. From having been a poor laggard in the outskirts of Europe Sweden became a modern industrialized and internationalized economy.

Table 2.1 Annual percentage growth rates of GDP per capita in Sweden, Germany, Finland, the Netherlands, the U.K., and the U.S, 1870-2007 (constant prices)

	Sweden	Germany	Finland	Netherlands	U.K	U.S
1870-1890	2.5	1.8	1.8	0.3	1.2	2.1
1890-1930	2.2	-0.7	1.8	0.9	0.9	1.4
1930-1975	2.7	2.5	3.3	2.0	1.7	2.2
1975-1995	1.1	1.8	1.7	1.7	2.0	2.1
1995-2007	3.1	1.4	3.7	2.4	3.0	2.1

Source: Bolt and van Zanden 2013

The 1970s however was a decade in which Sweden's position vis-à-vis comparable countries deteriorated. The country fell behind relative to countries like Germany, Finland, the U.K., the U.S. and indeed the OECD average.[134] Having suffered a deep economic crisis in the early 1990s, the Swedish economy recovered and annual growth rates rose above European and OECD averages. The objective of this chapter is to provide a more detailed picture of the development behind the aggregates.

2.2 Economic performance and industrial structure before and during the World Wars

The decades around the birth of the twentieth century marked a period of profound transformation in the Swedish economy. The primary sector as well as associated industries experienced intense international competition and lower prices. A period of significant restructuring followed, first and foremost within the iron and steel establishment, of which some firms were modernized and some were closed down.[135] While raw material extracting industries began experiencing the negative side of international competition and technological development, other parts of the manufacturing sector enjoyed and benefitted from the opportunities offered by the new technologies associated with the second wave of industrialization and the increased global market integration of the late 1800s.[136] Being a small country with only a limited domestic market, developing internationally attractive products was crucial to Sweden's economic prospects. The decades around the end of the nineteenth century experienced a number of groundbreaking innovations being developed by Swedish inventors.[137] The new businesses based upon inventions such as de Laval's separator, Ericsson's telephone, and Wenström's electricity transmission technology did not have any direct link to resource extraction, but were standalone

[134] Henrekson et al. 1996 p. 240

[135] Schön 2000 p. 201f

[136] Schön 2000 p. 204f

[137] Ohlsson 1992 p. 25-26

entrepreneurial successes.[138] Restructuring of the primary sector and related industries together with a high rate of invention and entrepreneurial activity laid a new basis for Swedish competitiveness.[139] No other industrialized country kept up with the Swedish growth rate during the period 1870-1910.[140] The advance of engineering industries at the expense of the primary sector continued unabatedly into the 20th century.

The First World War favored the burgeoning Swedish industrial structure as demand for iron and steel, fabricated metal products, engineering products, wood products, and pulp and paper grew.[141] Export volumes increased prior to and during the war and higher prices on Swedish goods (due to an appreciation of the currency) contributed to higher profits in the war years.[142]

The interwar period witnessed a return to increased international competition. The two interwar decades were of different character. While the 1920s was one of rationalization and concentration, the 1930s was transformative with intense innovation and startup activity characterizing the decade.[143] Thus, out of the interwar period came not only restructured firms based on prior innovations but also new innovative firms.[144] Erik Dahmén has called the interwar period one of *industrial metamorphosis*:

> "One cannot, it is true, point to any completely revolutionary, entirely new, lines of development to compare with those that emerged during the last decades of the 19th century. But the economy proceeded so rapidly along the path it had entered upon that this alone would have drastically altered the

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[138] Schön 2006b

[139] Carlsson et al. 1979 p. 48-9. The structural change that the Swedish economy underwent during this period is largely neglected in the work by Michael Porter (1990 p. 331ff) who only emphasizes the importance of the part of the economy that is related to the extraction of natural resources and firms established in direct relation to it.

[140] Schön 2000 p. 225

[141] Carlsson et al. 1979 p. 49

[142] Schön 2000 p. 274

[143] Dahmén 1970 p. 385 ff; Schön 2000 p. 304ff, 354ff; Lundh 2002 p. 141

[144] Schön 2000 p. 323

> character of industry and, thereby, of society in general. When the emergence of the many new, important, and previously more or less unknown, lines of development are also taken into account, one has ample reason to use the term 'metamorphosis'."[145]

The electric motor played a central part in this metamorphosis. The development of small and effective electric motors enabled installation in individual machines in the manufacturing sector and made for higher productivity and flexibility. In addition, the development of smaller motors resulted in the birth of new consumer goods firms that manufactured products such as washing machines, vacuum cleaners, refrigerators etc.[146]

The crisis-ridden early 1930s mark the dawn of a period of strong GDP per capita growth and an era under which Swedish export industries prosper. In accordance with the prevailing political trend (Keynes influential book *The General Theory of Employment, Interest and Money* was released in 1936) the Swedish social democratic party promoted expansionary policy in order to stimulate demand.[147] Large investments in infrastructure (road and electricity grids) fueled growth in the manufacturing sector.[148] Hence, although Swedish exports fared relatively well during the protectionist 1930s, the positive development also depended on domestic demand.[149]

The protectionism that characterized international trade during the 1930s became even more pronounced during World War II. As demand on Swedish export markets decreased, the relative share of Swedish industrial production supplied in the domestic market increased.[150] Domestic demand was stimulated by public investments, not least defense procurement. The political trend of the 1930s became even more pronounced during the

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[145] Dahmén 1970 p. 385

[146] Schön 2000 p. 314

[147] In the 1930s onwards a group of Swedish economists expressed ideas similar to those expressed by Keynes. Scholars of the so called *Stockholm school* were optimistic about the potential of politicians fine tuning the business cycle. See Jonung (1999).

[148] Lundh 2002 p. 141

[149] Schön 2000 p. 351-2

[150] Schön 2000 p. 359

1940s as the government sought to control aspects of the free market economy which had not been subject to political intervention previously. Both the credit market and foreign exchange trading were regulated in a quest to monitor the flow of capital.[151] The end of the war marked a shift from short term Keynesian stabilization policy to long term strategies with the ambition of supporting structural change and long term growth.[152] This change in policy orientation was to have a significant bearing on Swedish postwar economic performance.

2.3 The successful postwar decades

The period from 1950 to 1973 has been described as unique in the history of European modern economic growth. High growth rates, nearly full employment, and low volatility and inflation were notable features of this era. The decades saw the Swedish economy prosper. The literature points to several factors that explain why the Swedish economy was particularly well-disposed to growth in the postwar period. The industrial structure founded around the turn of the century and restructured in the interwar period proved to be successful, as much of the postwar growth was generated by already established firms.[153] As Sweden was not directly involved in the war, it entered the postwar period with intact production facilities readily poised to pick up the demand from war-damaged European economies. Peter Temin (2002) has pointed to an intense reallocation of resources as being an important determinant of the rapid development experienced by European economies in the postwar decades.[154] Temin argues that interrupted trade in the interwar period slowed structural transformation down. This process was further held-up by the Second World War. The European reallocation of resources from agriculture to manufacturing in the postwar period is likely to have increased demand for Swedish capital goods.

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[151] Schön 2000 p. 362-3

[152] Schön 2000 p. 364

[153] Carlsson et al. 1979 p. 48; Jagrén 1988

[154] Temin 2002

Falling transport prices benefitted countries like Sweden, situated on the outskirts of Europe. A devaluation of the Swedish currency in 1949 made Swedish products attractive and was thus a contributing factor to the ensuing export expansion.[155] In particular, the business cycle upturn related to the war on the Korean peninsula (June 1950-July 1953) kick-started Swedish exports. High profits allowed for modernization of production facilities and the acquisition of new machinery. Hence, in the beginning of the 1950s, the Swedish manufacturing sector was a comparatively well-oiled piece of machinery, comfortably equipped to meet domestic and foreign demand.

A wave of trade liberalization favored the Swedish position. The General Agreement on Tariffs and Trade together with the establishment of free-trade zones like those of the EEC and EFTA contributed to increasing market integration.[156] EFTA, the free-trade zone in which Sweden partook exempted only manufacturing products from duty. As manufacturing products constituted the lion's share of Swedish exports the country benefitted more from EFTA than countries with smaller shares of such products in their total export volumes.[157] Stability was promoted through the Bretton Woods agreement which established a system of fixed exchange rates. In 1970 the volume of Swedish exports was four times that of 1950 and between 1958 and 1965 industrial output rose by on average 7.5 percent annually; a very high rate by international comparison.[158] Likewise, the productivity growth rate of the 1950s and 1960s was high relative to the international experience.[159]

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[155] Eliasson 1967 p. 33; Dahmén 1992 p. 57

[156] Lundh 2002 p. 143

[157] Carlsson et al. 1979 p. 57

[158] See Schön (2000 p. 381) for the former numbers and Carlsson et al. (1979 p. 57) for the latter.

[159] Nabset 1971 p. 84

Table 2.2 Industries' share of exports 1951/1955 and 1971/1975

Product group	Export share 1951/1955	Export share 1971/1975
Wood products	13.7	6.7
Pulp	20.0	7.8
Paper and paper products	11.0	9.2
Iron ore	9.2	4.8
Metals and metal products	12.0	13.7
Machinery and transport equipment	20.8	40.5
-of which vehicles	1.5	10.8
-of which ships	5.5	5.3
Other	13.3	17.3
Total	100	100

Source: Schön 2000 p. 382

Both exports and production now witnessed the full realization of the structural shift which had started around the turn of the century 1900. This shift meant that engineering products became more important relative to wood products, pulp, iron ore, and other products with less value added.[160] High quality human capital together with relatively high wages and a compressed wage structure contributed to the growth of knowledge intensive production.[161] However, innovation and renewal not only occurred in engineering industries, but also in less knowledge intensive industries.[162] It has been suggested that the period running from the end of the war until the mid-1960s is distinguished by numerous product innovations targeting both old and new markets as well as process innovations.[163] Another account provides a somewhat different picture by demonstrating that breakthrough innovations were a phenomena limited to a small number of industries (see

[160] Schön 2000 p. 381-2

[161] Schön 2000 p. 383-4; Ljungberg 2004; Ljungberg and Nilsson 2009

[162] Dahmén 1992 p. 57-8. The textile and clothing industry did not undergo this positive development.

[163] Dahmnén 1992 p. 57-8

table 2.3).[164] That same account also shows however that Swedish industries were world leaders in adopting new technology.[165]

Table 2.3 Major innovations in Swedish manufacturing industry, 1955-1975

Industry	Innovations
Electrical machinery and apparatus	High-voltage DC, high-pressure technology in full-scale industrial processes, thyristor-driven electric locomotives, retarders, furnaces with magnetic agitation, the ASEA-SKF process (vacuum treatment during liquefaction)
Iron	Concentration methods, hauling systems, transport systems for underground mines
Steel	Stainless pipes, acid-proof pipes, refractory pipes, cladding pipes, stainless blades, electro-steel methods, ladle metallurgy, rolling technology for special-steelworks, Kaldo furnaces, the Dored method, sponge iron methods.
Shipbuilding	Hydro mechanics, hull construction.

Note: The innovations are reported chiefly by IVA (Kungliga Ingenjörs-vetenskapsakademien/The Royal Swedish Academy of Engineering Sciences). Source: Carlsson et al. 1979 p. 141-144.

In this particular account, by Carlsson and colleagues (1979), respondents (IVA members) were asked to assess the position of top Swedish firms in various industries vis-à-vis foreign competitors during the 1940s, 1950s, 1960s, and 1970s.[166] Until the end of the 1960s Swedish firms enjoyed a competitive advantage in special steel, wood products, ships and shipbuilding methods, power transmission, automatic circuits for telecom systems, telephones, and transmission technology for telephones. Marine steam turbines and forest machines were two notable industrial sectors that moved from lagging to surpassing competitors during the 1960s. Other industries which achieved successful competitive positions were aircraft, semiconductors, electrical locomotives, information processing, power grid surveillance equipment, aero motors, and pharmaceuticals. According to the

[164] Carlsson et al. 1979 p. 138-54

[165] Carlsson et al. 1979

[166] Carlsson et al. 1979. See appendix A.

respondents, Swedish firms associated with petro-chemicals and plastics where behind their competitors throughout the period, while organic chemistry firms stayed abreast with competitors.

2.3.1 Social democratic rule and the Swedish model

Swedish postwar performance cannot be discussed without reference to the lengthy period of social democratic rule (1932-1976) and the Swedish policy model.[167] Important components of the model stem from ideas developed by Gösta Rehn and Rudolf Meidner, two economists working for LO (the Swedish trade union confederation), an organization with close links to the Social Democratic party. Rehn and Meidner's ideas were first presented to the LO congress in 1951 and were to exercise an increasing influence over Social Democratic policy from the mid-1950s onwards.[168]

The elements of the Swedish model fit well with the development of social democratic ideals and policies throughout the 1930s and 1940s.[169] A central tenet of this model was the relationship between the various parties of the labor market. The model drew on the agreement reached between SAF (the employers' federation) and the LO in Saltsjöbaden in 1938. The Satlsjöbaden agreement aimed at achieving industrial peace through consensus regarding the ambition to mutually respect the interests of the differing parties of the labor market.[170] Wage moderation and reinvestments of profits characterized the so called Saltsjöbaden spirit in practice. The Swedish model hinged on the trust placed by unions and the government in the ability of firm managers to make strategic and day-to-day decisions about production.[171] Furthermore, it presupposed the continuous growth of the manufacturing sector.

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[167] Model here refers rather to an economic-political action program than to a formal economic model (Holmlund 2003 p. 55). See Eichengreen (1996) for a discussion of the role of political institutions during the European post war growth epoch.

[168] Bergström 2003; Ekdahl 2003

[169] Lundberg 1985

[170] Lundh 2002 p. 164-6

[171] Eliasson and Ysander 1983

The Swedish model encompassed aims such as high and stable growth rates, full employment, a stable price level, and equal income distribution. This was in theory to be achieved through an elaborate combination of market economy economics, Keynesian stabilization policy, redistribution policy, and ambitious welfare reforms; the so called "mixed economy". The political program based on the Swedish model targeted fiscal, monetary and employment policy. The working of the model presupposed harmony between the three policy areas. Fiscal and monetary policy was mainly Keynesian, with a juggling of the budget balance so that there was a surplus balance in good times and a deficit balance in bad times. Although the Swedish model put pressure on industries to stay productive and competitive, demand policy was often expansionist, notably so in the period immediately following on the Second World War. From the end of the 1950s until the end of the 1960s policy closely followed the prescription set by the Swedish model and was largely restrictive.[172]

The practiced wage policy was one of the more salient features of postwar policy. The *solidarity wage policy* drew on the principle of equal pay for equal work. Wage was thus tied to the character of the work performed and not to a particular firm's ability to pay.[173] The background was that the economy was in reality split into a sheltered sector (housing industries such as construction, foodstuff, and wood products) and a sector exposed to international competition.[174] The limited competitive pressure enabled the sheltered sector to push up prices and thus pay higher wages in a way that was impossible for the competitive sector. The disparate conditions bred for an unfortunate movement of labor from the competitive to the sheltered sector.[175] The EFO model was constructed to turn this development so that the competitive sector instead was to drive wage bargaining. To an

[172] Erixon 2003 p. 108-10, 2010

[173] Schön 2000 p. 403

[174] Ohlsson and Vinell 1987 p. 243ff

[175] Lundh 2002 p. 195-6

increasing extent, this model came to influence centralized wage bargaining from the 1950s onwards.[176]

The Saltsjöbaden agreement restricted the possibility to compete for labor by offering higher wages. The solidarity wage policy reduced such opportunities even more. As a result wage differentials decreased; a central political aim of the social democratic party.[177] A second aim, of utmost importance to the structural development of the manufacturing sector, was that firms who were unable to pay centrally negotiated wages were either forced to rationalize or use other means to raise productivity in order not to lose ground and be shaken out.[178] The solidarity wage policy would thus ideally cater for a more rapid structural change. A consequence hereof was that the profit spectrum widened. In the political strive for equality new taxes were introduced, the most notable of which was a progressive tax on personal income.[179] High marginal income tax in the higher income brackets has been one of the prime measures to redistribute private income.[180] Statutory corporate income tax was also high, between 1950 and 1990 it varied within the range of 50-62 percent.[181] The high corporate income tax was compensated for by a range of tax reductions, the most notable of which were depreciation provisions and the investment fund system.[182] Additional regulations concerning the amortization on physical capital were also designed in a manner that was beneficial to the firm establishment. Through

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[176] Lundh 2002 p. 209. EFO is short for the surnames of the developers of the model: Edgren, Faxén, and Odhner of TCO, SAF, and LO respectively.

[177] Schön 2000 p. 403

[178] Lundh 2002 p. 194

[179] Schön 2000 p. 404-5

[180] Henrekson et al. 1996 p. 272

[181] Henrekson and Jakobsson 2000 p. 8

[182] Södersten and Lindberg 1983; Henrekson 1996 p. 58-60. The idea behind the investment fund system was that firms would distribute investments over the business cycle, preferably in downturns, and thereby stabilize the economy .The government exercised control over the distribution of investments through a requirement that prescribed that half of the funded capital had to be deposited on a non-interest bearing account at Riksbanken (the central bank). In the hands of the state, the funds were used as a stimulation tool and met with some initial success in evening out the manufacturing investment cycle (see e.g. Eliasson 1966).

these arrangements firm tax regulations sought to stimulate investments.[183] Further stimulus to existing structures was provided by a tax relief on stock investments through so called mutual funds. As the relief favored firms already listed on the stock exchange it increased the distance to unlisted firms and thus indirectly disfavored the growth of small and medium sized firms.

The tax system was one way to control the allocation of capital. The regulation of the credit market was another. The credit market was not trusted to allocate capital in a socially beneficial way. The regulation sought to remedy the short-termism of private capital institutions and to allocate capital to strategically important areas.[184] The tax-exempted investment funds were likewise regulated and were thus an indirect economic policy tool. Another component of the regulation of capital was the currency control. This control was introduced during the Second World War as a means to defend the country from the economic effects of the war in line with the Bretton Woods agreement.[185] The intervention of war-time lingered for some 50 years in the Swedish economy although it was subject to liberalization, particularly during the 1960s.[186]

Labor market policy complemented the solidarity wage policy and was thus an important component of the Swedish model. The structural change resulting from the shake-out of unprofitable firms meant a growing amount of redundant labor, something that did not sit well with the goal of full employment. The government therefore had to fend simultaneously for low unemployment rates while also enabling the supply of competence to surviving and new firms. The ambition was to overcome unemployment through increasing labor mobility through the mechanisms of retraining, information, and forecasts.[187] Moreover, extensive welfare ambitions expanded the Swedish public sector. This growth of government absorbed primarily female labor as about a million women migrated from unpaid

[183] Henrekson 1996 p. 58-60

[184] E.g. housing. Schön 2000 p. 405-6.

[185] Nyberg and Viotti 2011

[186] Oxelheim 1990; Schön 2000 p. 406-7

[187] Schön 2000 p. 404

housekeeping work to salaried employment in the public sector between 1950 and 1975.[188]

Numerous reforms that would shape society and labor relations were implemented in the name of the Swedish model; namely social transfer systems related to retirement, sick and parental leave, and unemployment. During the 1970s labor relations were increasingly regulated by the passing of laws that endowed employees with an increasing share of work place influence (e.g. laws for worker participation, working environment, protection of employment, and shop stewards). By the late 1970s the Swedish model had become a comprehensive political and regulatory apparatus.

2.4 Slowdown and restructuring

Internationally, the first oil price chock in 1973 is taken to mark the end of the prosperous post-war decades. The 1970s witnessed both declining GDP and investment rates throughout Europe and falling employment and productivity (both in terms of GDP/worker and output/hour worked).[189] To add to the turbulence, 1973 was the year the Bretton Woods system, which had provided stability and restricted speculative capital flows, was formally terminated. Taken together, the events of the first half of the 1970s provided a radically changed economic environment. While the growth rates in Japan, the United States, and most European countries plummeted in the wake of the 1973 year oil price shock Swedish growth rates remained high until 1975. The Swedish post war epoch of growth therefore came to an end a couple of years later than was the case among most other industrialized countries.

The international situation now underwent turbulent adjustment. Changes included not only events (e.g. the aforementioned oil price shocks and the termination of the Bretton Woods system) but also processes unfolding over

[188] Sjögren 2008 p. 48

[189] Crafts and Toniolo 1996 p. 8, 25. While much effort has been put into explaining what factors that caused the slowdown, Crafts and Toniolo (1996) argue that rather than being disconcerting, the slower growth rates should be interpreted as a return to normal.

longer periods of time. The reallocation of resources from agriculture to manufacturing as suggested by Temin is one such process.[190] The structural disequilibrium inherited from the inter war period was more or less eliminated at the onset of the 1970s. The catch-up growth of war-torn countries embodies another, related, such development.[191] The catch-up process was rapid, by 1950 output and capital stock losses had already recovered and by 1970 the restructuring effect was more or less exhausted.[192] There were two sides to the European recovery; the demand for Swedish products decreased *and* competition increased.[193] At the same time, newly industrialized countries added competitive challenges to Swedish producers.[194] Gradually, markets for a range of Swedish industries reversed from sellers to buyers markets, as supply surpassed demand during the 1950s and 1960s. The increasing competition meant lower relative prices on Swedish export goods and thus a weakening of the national competitive advantage. By the mid-1970s the international downturn had manifested itself in Swedish GDP and industrial production. Productivity growth slowed down compared to the U.S. and other west European countries, reaching a trough in 1977 when productivity actually decreased.[195]

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[190] Temin 2002

[191] See for example Abramowitz (1986).

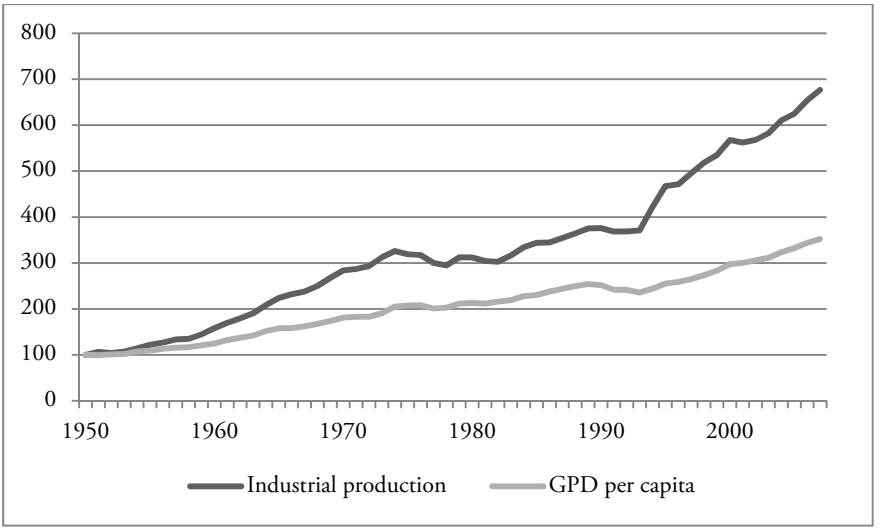
[192] Crafts and Toniolo 1996 p. 3, 21-2; Eichengreen 1996; Henrekson et al. 1996 p. 257

[193] Carlsson et al. 1979 p. 59

[194] Namely South Korea, Taiwan, Hong Kong, and Singapore. Carlsson et al. 1979b p. 18-25; Dahmén 1992 p. 59

[195] Lind 2003 p. 40

Figure 2.1 Industrial production and GDP per capita (constant prices) (1950=100), 1950-2007



Source: GDP per capita: Schön and Krantz 2012, industrial production: SCB. Base years recalculated by the author.

Although the apparent decline did not appear in the figures until the mid-1970s signs of malaise had been visible as early as the mid-1960s.[196] This is evident from decreasing net margins, declining solidity, and a falling investment ratio.[197] The international downturn in 1965/1966 did not sit well with high Swedish wages and as a consequence of these strains, executives increasingly had to deal with cost pressure.[198] The iron and steel,

[196] Krantz (2004) suggests that in comparison to 16 industrialized countries that, by 1970, had the same income level as Sweden, the Swedish economy had already begun to grow slowly from the 1950s onwards.

[197] Carlsson et al. 1979 p. 38-39; Dahmén 1992 p. 55-6; Schön 2006a p. 69

[198] Wissén 1983. Real product wages had risen to a level that was not sustainable in the long run (Wissén1983). The real product wage is the money wage in a specific industry deflated by the value of that industry's product (Lipsey and Harbury 1988 p. 423). It basically reveals to us that proportion of an industry's sales that is allocated to wages. An unsustainable real product wage implies that in a given industry there is insufficient revenue generated by sales to cover labor costs.

shipbuilding, and wood-related industries in particular faced a deteriorated business environment. The increase in competition was met primarily through enhanced efficiency through the rationalization of both production processes and work organization, and through mergers and acquisitions.[199] The literature reports a widespread inclination among executives to focus on rationalization in the beginning of the 1970s.[200] Extensive investments in energy efficiency and other means of rationalizing production were facilitated by beneficial tax policies. In addition, the 1960s and 1970s saw the rapid introduction of numerically controlled machines, CAD/CAM technology and the emergence of industrial robots.[201] This rationalization surge kept profitability on a high level throughout the first half of the 1970s and enabled strong wage increase.[202] It has been argued that the sustained aggregate profitability masked the fact that large parts of some industries consisted of plant that had become unprofitable and outdated.[203] The production structure installed in the beginning of the 1950s appeared very modern at the time but was now outdated in comparison to the equipment of industrial establishments in countries such as Japan which had invested in later vintages of physical capital. The initial advantages of not having been involved in the Second World War had now expired. A study of processes of obsolescence and renewal (between 1965 and 1977) shows that despite having received a relatively large share of total investments in manufacturing, the iron and steel, machinery and equipment, and

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[199] Rydén 1969, 1971; Jakobsson and Wohlin 1980 p. 254; Dahmén 1992 p. 58-60. See Carlsson et al. (1979, chapter 5) for an account of rationalization measures undertaken in Swedish firms in the second half of the 1960s and the first half of the 1970s.

[200] Wohlin et al. 1973 p. 85

[201] Lundh 2002 p. 231-6. CAD is short for *computer aided design*, and CAM for *computer aided manufacturing*.

[202] Porter argues that the widespread quest for rationalization (induced by high wages) throughout much of the manufacturing industry contributed to the development of a comparative advantage in labor saving technologies such as automated warehouse handling equipment and robots (Porter 1990 p. 345). Disadvantageous factor conditions thus not only spurred rationalization but bred competitive advantage in a growing industry. Several examples of innovations developed to increase efficiency are found in the steel industry: the Kaldo process in 1956, the ASEA-SKF ladle furnace in 1965, and the CLU process in 1973 all contributed to more effective energy saving production (Gyllenram et al. 2011 p. 197).

[203] Johansson and Strömquist 1980 p. 8-9

shipbuilding industries post lower profits and contain a higher share of employment working in obsolete plants throughout the period than other industries.[204] Conversely, various other industries receive a relatively small share of investment though nonetheless undergo renewal and achieve high profits. The matrix below shall be interpreted as follows-the diagonal falling from the top left corner to the bottom right corner represents industries in which renewal is proportionate to investments. The opposite diagonal line represents industries that have performed surprisingly poorly (e.g. machinery and equipment) or unexpectedly well (e.g. foodstuffs) given their particular level of investment.

Table 2.4 Investments and renewal in Swedish manufacturing industries, 1965-1977 *

Investment and production share**	Low gross profit share*** and high share of employment in obsolete plants	Medium gross profit share and mixed vintages	High gross profit share and large elements of renewal
Low	Textile, Rubber	Plastics, Non-metallic mineral products, Instruments	Foodstuff, Chemicals, Petrol
Medium	Iron and steel	Electrical machinery and apparatus	Mining
High	Machinery and equipment, Shipbuilding	Pulp and paper, Publishing and printing	Transport equipment, Fabricated metal products, Wood products

Note: *Investment- and production shares investigated for the period 1965-1975, gross profit shares investigated for the period 1969-1977. ** Share of the total investment and production in the manufacturing sector. ***Gross profit share equals the gross -profit-to-value added ratio. Note that a high capital share (i.e. high capital intensity) will bias the gross profit share. Source: Johansson and Strömquist 1980 p. 13.

[204] Johansson and Strömquist 1980 p. 9-10. The same applies, to some extent, to the pulp and paper industry.

The political and economic implications of a disproportional relationship between investments and renewal differed with industry. Machinery and equipment absorbed a high share of total investments and employed the highest number of people of all industries but performed comparatively dismally. Shipbuilding employed fewer people but was of fundamental importance to the Swedish west coast.[205] One must also take into consideration the value chains of which the different industries are each a part. Imbalances between renewing and obsolete industries in one and the same value chain may cause bottlenecks to arise. Problems in both the iron and steel and shipbuilding industries arise also in other studies which show that Swedish firms had lost ground towards foreign competitors in both crude and special steel, as well as shipbuilding.[206] In the period spanning from 1965 to 1977, the truly dynamic industries are found in the field farthest to the right (table 2.4). Elsewhere it has been shown that developments in electrical machinery and apparatus and telecommunications were particularly favorable.[207] In these industries top Swedish firms either moved ahead or maintained leading positions against top foreign competitors.[208]

2.4.1 Crisis policy

The first half of the 1970s saw reassurance in both the political and industrial spheres.[209] Industry representatives expected that capacity utilization would increase again prior to or during the second half of the decade.[210] The International Iron and Steel Institute predicted an increase in

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[205] Johansson and Strömquist 1980 p. 188-94

[206] See appendix A. Carlsson et al. 1979; Johansson and Strömquist 1980. Note that Carlsson et al. (1979) presents no clear-cut category for the machinery and equipment industry.

[207] Carlsson et al. 1979

[208] Carlsson et al. 1979. See appendix A.

[209] One example of the optimistic outlook which prevailed among politicians is the planning of a steel mill in Luleå in the early 1970s. The mill would produce some nine million tons of crude steel. The number is to be compared to total Swedish production at the time which was some five million tons (Jonsson 2011 p. 173). The mill in Luleå never left the drawing-desk.

[210] Wohlin et al. 1973 p. 83ff

West European steel consumption of some 70 percent between 1970 and 1985.[211] The wave of investment and modernization in Swedish production facilities, financed partly by the now freely available investment funds, should be mentioned with this international background in mind. High prices fetched by raw materials in the international business cycle upturn in 1973/1974 favored Swedish suppliers and primary processers of these raw materials. Political pressure on firms to share the resulting "abnormal" profits with their employees increased significantly in the first half of the 1970s.[212] In addition to wage increases, the large profits enabled extensive investments in production facilities.

When the international economy initially slowed down in the early 1970s the Social Democratic government launched a stimulus program in order to "bridge-over" what was believed to be a temporary downturn. The goal was to uphold full employment by accommodating external supply and demand shocks through the use of Keynesian stimulus policy.[213] Crisis-ridden firms were offered financial support so as to not be forced to lay off personnel and in order for them to be able to build up stocks so that the anticipated rise in demand could be met.[214] When the crisis deepened and its structural dimensions became apparent, the center right government employed acute measures to support crisis-hit industries. As part of this program, several large firms in particularly affected industries were nationalized. The state enterprises Svenska Varv AB and Svenskt Stål AB were founded in 1977 and 1978 respectively to restructure the shipbuilding and iron and steel industries.[215] Major cuts in employment combined with the restructuring of production were some features of the program designed to save these old and important industries, a program whose implementation drew on the consent of unions, firm management, and the government. Expansion of the public sector was deployed as a weapon to keep unemployment down

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[211] Ruist 1985 p. 163

[212] Tson Söderström 1983

[213] Schön 2000 p. 440

[214] Jörberg 1991 p. 53; Hansson and Lundberg 1995 p. 163-6; Schön 2000 p. 440. See also article by Audia et al. (2000): "The paradox of success: an archival and a laboratory study of strategic persistence following radical environmental change".

[215] Gawell and Pousette 1985; Ruist 1985; Örtengren 1988

throughout the 1970s and some years into the 1980s.[216] This ambitious curbing of the crisis was costly; between 1974 and 1985 the public expenditure ratio rose from 47.5 percent to 63.3 of GDP.[217] Up until the international debt crisis in 1981/1982, foreign loans were used to finance the crisis policy.[218] The effects of the increasing budget deficit and extensive borrowing fed back on each other and created a vicious circle.

The structural crisis has been called a cost crisis, Swedish export industries suffered from high costs in general and rising wage costs in particular.[219] The Swedish model was no longer viable. The tradition since the 1930s of holding back excessive wage increases had now broken down. In 1976 the newly elected center right government turned from the offensive stabilization policy practiced by the Social Democratic government to a defensive devaluation policy. The authorities sought to adjust the cost profile of Swedish export industries in response to changes in the international environment through devaluation.[220] The idea was to support exports through lowered relative prices, alleviate cost pressures, and to make hiring new employees an attractive strategy for the manufacturing sector.[221] When the Social Democrats regained the power in 1982, they sought to kick start the economy by another devaluation of some 16 percent. The devaluation in 1982 has been taken to mark a shift from a policy aiming at the adjustment of the currency in order to *regain* competitive advantage to an aggressive currency policy seeking to *create* competitive advantage.[222] Furthermore, it has been argued that devaluation was the only way in which the Social Democratic government could escape rising unemployment since the potential to further expand the public sector was by now more or less exhausted.[223] Along with the devaluations, the Social Democratic

[216] Schön 2000 p. 475-9

[217] Jakobsson 1997

[218] Schön 2000 p. 493

[219] Calmfors 1979

[220] Henrekson 1991 p. 45-6

[221] Jonung 1991 p. 39

[222] Henrekson 1991; Jonung 1991, 2000

[223] Herin 1991 p. 139

government continued with the restructuring of heavy industries and placed an emphasis on active labor market policies, measures that were in line with the Swedish model.[224] These measures helped to constrain Swedish unemployment at a low level until the crisis of the early 1990s.

2.5 Boom: the 1980s

The devaluations affected the public and the private sector in different ways. Interest rates on foreign loans increased which put even more strain on public finances while the devaluation created a cost advantage for export industries, with high profits as a result. The devaluation had a positive effect on the balance of trade which was on a positive trajectory from 1984 throughout the rest of the decade although the cost advantage of export industries was gradually eaten up by wage drift.[225] The increasing interest rate burden put on the public finances led to budget restrictions being introduced in the first half of the 1980s. However, the restrictive fiscal and monetary policy practiced in the wake of the devaluation was only sustained for a short period. Expensive labor market programs together with a large social welfare apparatus contributed to high levels of public expenditure during the second half of the 1980s.[226]

The soaring debt ratio and a heavy interest rate burden troubled the public balance sheet. The increasing inflow of foreign capital into internationalized firms opened up opportunities for increased domestic savings. In order to be attractive to commercial actors, treasury bonds had to be competitive, but issuance of competitive treasury bonds did not sit well with the regulation of commercial banks and so the latter was gradually unraveled.[227] A stepwise deregulation was initiated in 1983 and was fully realized in 1985 through the so called November revolution.[228] While the first venture capital firm

[224] Erixon 2011b p. 269

[225] Schön 2000 p. 500-1

[226] Henrekson et al. 1996 p. 265-6

[227] Schön 2000 p. 495

[228] Svensson 1996

was founded by the government in 1973 the first private firm was established in 1983.[229] Additional reforms sought to improve the entrepreneurial climate. One example was the introduction of a so called OTC (over the counter) market in 1982.[230] The OTC market allowed trade in firms with much less market value than firms listed on the stock exchange.[231] The idea was that small and medium sized firms would get increased access to growth capital and eventually graduate to the Stockholm stock exchange.[232] Increased profits and regulatory alleviations made for an era of credit expansion characterized by generous lending from commercial banks throughout the 1980s.[233] Coupled with a tax system that favored borrowing and the purchase of shares, the deregulation of the domestic credit market made for intense stock trading and large investments, particularly in commercial buildings.[234] The heated domestic property market ignited a building boom. The building frenzy's demand for workers initiated upward pressure on wages in the manufacturing sector as competition to attract labor increased.[235] As a result, the sector became all the more vulnerable in the late 1980s.

The 1980s was a decade associated with the initiation of tax reform. The tax ratio had increased from around 40 percent in 1970 to approximately 50 percent in 1980.[236] In the beginning of the 1980s the marginal tax rate had reached 85 percent.[237] A combination of high tax rates and narrow tax bases gave rise to non-uniform taxation, resulted in various types of tax planning,

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[229] Herzog 1990

[230] Örtengren 1985 p. 114

[231] Awareness of the importance of small firms spread during the 1980s. Publicly run start up inspiration programs were introduced in the early years of the decade (Nordisk Ministerråd 1993 p. 6)

[232] SOU 1981

[233] Jonung 1994 p. 12; Ingves and Lind 1998

[234] Henrekson et al. 1996 p. 255-6; Schön 2000 p. 503-7; Erixon 2011b p. 269

[235] Schön 2000 p. 505

[236] Johansson 2007 p. 303

[237] Birch Sørensen 2010

affected the supply of labor, and distorted investment.[238] Altogether, the tax system was found to be in need of reform. Debates and negotiations where lengthy and while some preliminary steps were taken during the 1980s a final resolution was not reached until 1990-1991.[239]

The second half of the 1980s was a period of a significant gross increase in both work place size and the number of jobs available in the Swedish economy.[240] This expansion is mainly attributable to the service sector. To some extent the increase of service firms is explained by vertical disintegration; namely, activities that were once performed within the firm are now in turn being purchased externally.[241] Widespread rationalization was undertaken in parts of the manufacturing sector. Workplaces in industries such as wood products, pulp and paper, and iron and steel became increasingly scarce.[242] Work-place development in knowledge intensive industries was mixed. There was an increase in work place development amongst engineering industries whereas that in high tech industries experienced deterioration.[243] Employment in the aggregate manufacturing sector stagnated in the 1970s whereas employment in knowledge and R&D intensive industries grew up until 1975 and from thereafter it declined.[244] The white collar work force in these two groups of industries increased up until the second half of the 1980s.

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[238] Norrman and McLure Jr. 1997; Agell et al. 1999

[239] See Santesson (2012 ch. 8) for a brief account of the development and an account of the internal debates of the Social Democratic party.

[240] Davidsson et al. 1994

[241] Bjuggren and Johansson 2009. Knowledge intense service firms employed 30 percent more people in 1989 than in 1985 (Davidsson et al. 1994 p. 57). Over the same period, temployment in such firms is distributed over 71 percent more work places (Davidsson et al. 1994 p. 55)

[242] The number of work places in wood, pulp, paper, iron and steel decrease by 8.5 percent between 1985 and 1989 (Davidsson et al. 1994 p. 55).

[243] The number of work places in engineering increase by 3.3 percent between 1985 and 1989 whereas the number of work places in and in high-tech industries decrease by a marginal -0.4 (Davidsson et al. 1994 p. 55).

[244] Ohlsson 1992 p. 36

Telecommunications, information technology, software and pharmaceuticals are argued to have been the more dynamic industries of the 1980s.[245] These industries achieved an annual productivity increase of nearly 10 percent between the mid-1980s and the mid-1990s with the rest of the manufacturing sector trailing far behind (especially in the 1980s).[246] The number of employees in information- and communication technology (ICT) firms rose by some 25 percent until the end of the 1980s from the mid-1970s.[247] Large office complexes in locations such as Kista were constructed to house firms in these industries. Additionally, science parks for academic spin-off firms in sectors such as pharmaceuticals and biotechnology were completed around the universities of Lund and Linköping.[248]

The growth of Swedish business enterprise R&D in the 1970s and 1980s overtook corresponding growth rates in all comparable countries.[249] Sweden was the only country in the world during the second half of the 1980s which recorded a rise above three percent in the percentage of GDP devoted to R&D.[250] Swedish business R&D is argued to have been highly skewed towards the development of products rather than processes.[251] In 1989 product development received seven times more investments than process development.[252] The distribution was even more distorted in knowledge and R&D intensive industries where twelve times as much was spent on the development of products compared to the development of new processes.[253]

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[245] Schön 2000 p. 505, 511-2

[246] Ohlsson and Vinell 1987 p. 132; Hansson and Lundberg 1995 p. 96; Schön 2000 p. 484

[247] Johansson 2003

[248] Schön 2000 p. 512. See also Ohlsson (1991 p. 67-71).

[249] Ohlsson 1992 p. 38. Large countries such as the U.S., Japan, the U.K., and Germany; and small countries including Finland, the Netherlands, Belgium, Denmark etc. (Ohlsson 1992 p. 38).

[250] Ohlsson 1992 p. 38; Henrekson et al. 1996 p. 278. This number regards percent of GDP generated by the manufacturing sector.

[251] Ohlsson 1992 p. 38-9

[252] Ohlsson 1992 p. 38-9

[253] Ohlsson 1992 p. 39

In the mid-1970s knowledge and R&D intensive industries together accounted for more than 80 percent of total business R&D.[254] Large multinationals were the dominant R&D spenders. In 1992 ABB (ASEA), Ericsson, Saab-Scania, and Volvo accounted for 70 percent of total R&D expenditures outlaid in the business sector.[255]

During the 1970s and early 1980s, Swedish export industries evolved towards increased specialization in knowledge intensive products.[256] However, the development came to a halt and was to some extent reversed during the second half of the 1980s. By 1987 the trade balance of the capital intensive industries had overtaken that of the knowledge intensive industries.[257] The export performance of the truly R&D intensive industries was even less convincing than that of other generally knowledge intensive industries.[258] On the other hand, the R&D intensive industries outdid the manufacturing sector on the whole in terms of growth in production volume.[259] The adverse trends have been explained by a) a high rate of domestic consumption of R&D intensive products, in particular of electronics, b), a Swedish specialization in producer goods with long life cycles (i.e. system technologies characterized by incremental technological change) for which demand developed less dynamically than for consumer goods (e.g. personal computers and cell phones) or mass produced input

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[254] Ohlsson 1992 p. 39. Knowledge intensive industries undertook 46 percent of total business R&D while R&D intensive industries undertook 35 percent of it (Ohlsson 1992 p. 39).

[255] Ohlsson 1992 p. 153

[256] Ohlsson and Vinell 1987 p. 87-9; Ohlsson 1992 p. 31; Hansson and Lundberg 1995 p. 85

[257] Ohlsson 1991 p. 22-3. Jagrén (1993 p. 83-7) shows that capital intensive firms advance up the list of Sweden's largest (in terms of employment) firms during the 1980s.

[258] Ohlsson 1992 p. 30. Ohlsson and Vinell (1987 p. 61) classify all of the following as R&D intensive-the development and production of electronics, computers, radios, television, communication equipment and apparatus, instruments, pharmaceuticals, aircraft, electric motors and generators. Knowledge intensive industries include household durables, investment goods, and shipbuilding (ibid). The same classifications are used by Ohlsson (1992).

[259] Ohlsson 1992 p. 32

goods (e.g. semiconductors and integrated circuits), and c) by high inflation.[260]

Credit market deregulation, increasing specialization, a more pronounced international division of labor, and a limited domestic market gave rise to intensified foreign contact during the 1980s.[261] Firms of all sizes internationalized, though the phenomenon was more prevalent among larger firms.[262] The flow of Swedish capital to foreign countries was destined not only for the establishment of foreign subsidiaries but also, especially following the abolition of currency control in 1989, towards commercial real estate.[263]

The second half of the 1980s was an interval characterized by extensive investments, heated stock and real estate markets and rapid asset price inflation.[264] However, the foundation upon which the boom was built was frail. All too frequently, real estate served as collateral for money borrowed from Swedish banks. Both banks and borrowers were thus increasingly dependent upon the booming value of property and the continued investments therein. The value of property was in turn heavily influenced by property valuation experts. Weaknesses afflict all valuations, one being expectations regarding the future. Accordingly, it is argued that bad valuation methods contributed to the real estate frenzy of the late 1980s.[265]

2.6 Bust: the financial crisis in the early 1990s

Several unfortunate developments turned the boom of the 1980s into a bust; the international business cycle downturn in 1990/1991, the long-term interest rate increase on the important German loan market (in the wake of

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[260] Ohlsson 1992 p. 32-3

[261] Schön 2000 p. 514-5

[262] Eliasson 1985a p. 22

[263] Schön 2000 p. 505

[264] Englund 1999

[265] Lind 1998

the reunification), a loss of the post-devaluation cost advantage, and the poorly timed "tax reform of the century".[266] High interest rates dampened the will to invest and after the finance company Nyckeln ("the Key") suspended their payments in September 1990 a full-fledged financial crisis set in. Defaulting investment companies left Swedish banks exposed to considerable credit losses. High interest rates also dampened private borrowing and thus added to the inability of banks to meet the statutory capital cover ratio. The Social Democratic government responded to the solvency problems by guaranteeing deposits in all Swedish banks.[267] In an attempt to build confidence in the Swedish currency the government pegged the *krona* to the European ECU in May 1991. The pegging saved the currency from aggressive speculation only as far as the summer of 1992. In a desperate attempt at defending the *krona* the overnight interest rate was raised to 500 percent on one occasion in September 1992. In November the same year, the currency was allowed to float by the center-right government.[268] The decision to let the currency float resulted in a de facto depreciation of 25 percent.[269] Decreased investments and consumption largely contributed to a negative development of Swedish GDP for three consecutive years (1991-1993).[270] The crisis was a protracted one and in terms of employment and real income, it was the most detrimental since the depression of the 1930s.[271] Unemployment rose from 1.7 percent in 1990 to 9.3 percent in 1994.[272] Internationally, only Finland's crisis was on par with the Swedish experience.[273] The budget deficit soared and the center-right

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[266] Tson Söderström et al. 1994 p. 25-9; Schön 2000 p. 505-7; Erixon 2011b p. 269-70. The tax reform e.g. lowered the progressive tax on personal income.

[267] Ingves and Lind 1998; Englund 1999

[268] Jonung 2000

[269] Lund 2002 p. 228

[270] Jonung 1994 p. 7f

[271] Hagberg and Jonung 2005

[272] Erixon 2011b p. 279

[273] Both Finland and Sweden were small open, corporatist economies located on the outskirts of Europe. The macroeconomic pattern in the two countries during the 1980s shared many characteristics; a deregulation of the credit market, increasing employment, increasing wages, a commercial real estate boom, and high inflation. In 1989 however, the Finnish government

government shifted gradually to a restrictive economic policy.[274] Restrictive economic policy in times of high unemployment ran counter to the ideas of the Swedish model.[275] However, even though the budget was restricted, room was made for ambitious active labor market policy. In 1994 7.3 percent of the total labor force was engaged in labor market programs.[276]

The extensive job losses during the 1990s crisis stand in stark contrast to the relatively modest losses during the slowdown of the late 1970s and early 1980s.[277] The trends relating to employment and the work place of the late 1980s intensified during the financial crisis. Jobs vanished from the manufacturing and public sectors, and were created in the private service sector.[278] In the manufacturing sector, jobs were shed from firms of all sizes while large firms generally fared worse than small firms.[279] The trends seen in the 1980s; shifts from manufacturing to service and from large to small firms, were even more pronounced during the years of financial crisis. Such trends persisted throughout the recovery year 1994.[280] As these trends cut through both upturns and downturns they must be taken to reflect a long-term structural shift with regard to employment in both sectors and firms of different sizes.

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undertook a revaluation of the currency in order to cool the heated economy (Hagberg et al. 2006). Following initial devaluation of the Finnish *mark* in 1991, floatation was the course of action followed in 1992.

[274] Erixon 2011b p. 268-73

[275] Although on occasion, restrictive policy had been practiced in downturns in the name of the Swedish model, particularly in 1971.

[276] Erixon 2011b p. 277

[277] Jonung 1994

[278] Numerous jobs were also lost in the public sector (Davidsson et al. 1996 p. 41).

[279] Davidsson et al. 1996 p. 65

[280] Davidsson et al. 1996 p. 43, 48

2.7 A new dawn: performance in the post-crisis 1990s and in the new millennium

Collectively, the "tax reform of the century" (formalized after around a decade of negotiations and smaller reforms), fiscal austerity measures, the introduction of strict rules regarding fiscal discipline and an inflation target were all deployed as tools to restructure the ravaged sovereign finances during and after the financial crisis of the early 1990s.[281] Restrictive monetary and fiscal policy was, with few exceptions maintained throughout the period studied in this thesis.[282] The deregulation of formerly controlled markets continued as a range of product and service markets now opened up to private actors and price competition (e.g. telecommunications, transport, and electricity).[283] Extensive labor market changes (e.g. decentralized wage negotiations, flexible contracts of employment etc.) which had been ongoing since the 1980s, continued together with emphasis moving away from targeting low unemployment towards focusing on low inflation. Hence, the Swedish model became an even more anachronistic description of Swedish policy orientation during the 1990s and 2000s.[284]

Although a profound shakeout of unprofitable firms and workplaces took place during the 1990s crisis, the crisis was by and large due to financial structures rather than the real economy. While productivity picked up as early as during the crisis, GDP growth resumed in 1994. The productivity increase in the period 1995-2006 has been called a 'miracle'.[285] Several explanations concerning the strong productivity growth experienced during and after the crisis have been put forth; the shakeout of unprofitable firms, job terminations, and increased foreign demand thanks to the depreciation of the currency supported by generally favorable international economic

[281] Erixon 2011b p. 272

[282] Erixon 2011b p. 306

[283] Erixon 2011b p. 274

[284] Lundh 2002 (ch. 5)

[285] Erixon 2011b p. 305

conditions in the 1990s.[286] As growth continued after the crisis, explanations came to revolve around the role of ICT and the resolution of the Solow paradox.[287] In particular, learning among users has been emphasized as being central.[288] Complementary explanations to the strong productivity growth center on both the deregulation wave starting in the 1980s and immaterial investments (R&D, on-the-job training, marketing etc.).[289]

A floating exchange rate increased the attractiveness of Swedish products and allowed for a growing trade surplus, and a growing export share of GDP.[290]

[286] Edquist 2010. Temin (2006) and Rhode and Toniolo (2006) describe the 1990s as a decade to be compared with the roaring 1920s and the period of postwar growth in the 1950s.

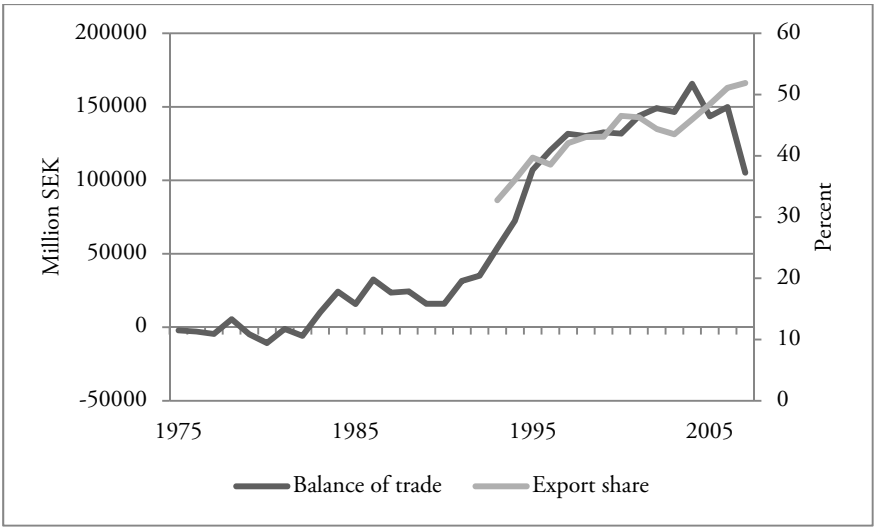
[287] Lundgren and Wiberg 2000; Lind 2002; Apel and Lindström 2003; Gunnarsson et al. 2004; Mellander et al. 2005; Edquist and Henrekson 2006; Edquist 2009. Swedish labor- and total factor productivity between 1995 and 2005 was second only to Ireland (Edquist 2010).

[288] Mellander et al. 2005; Gunnarsson et al. 2004

[289] Edquist 2010; Calmfors 2013

[290] Erixon 2011b

Figure 2.2 Balance of trade (current prices), 1975-2007 and export share of GDP (current prices), 1993-2007

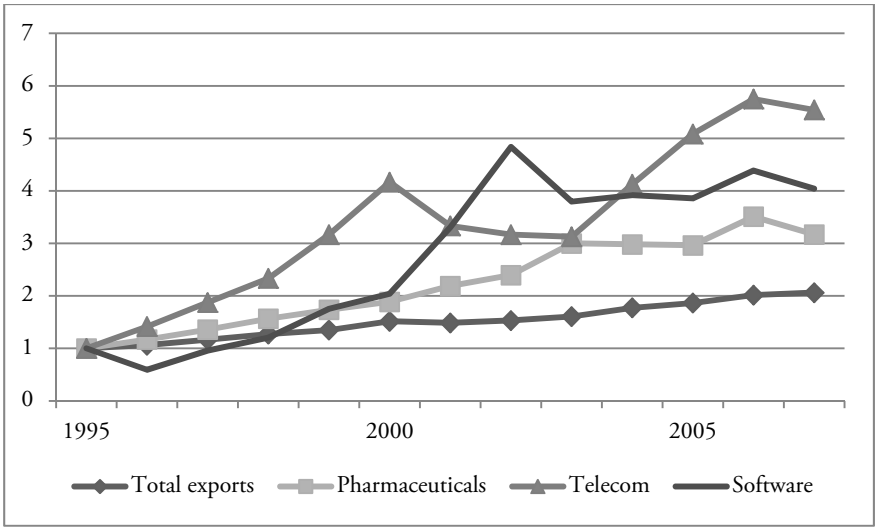


Source: SCB.

Exports of various industries developed along individually unique pathways. For instance, raw material-processing sectors including wood, pulp, paper, rubber, non-metallic mineral products, iron and steel all performed weakly when compared to the export total of the manufacturing industry. Fabricated metal products, machinery and equipment, and other transport equipment (including firms such as Volvo Lastvagnar and Scania) also experienced weaker growth trends than total exports. While electrical machinery and equipment, motor vehicles, and instruments developed more or less along parallel lines to the export total of manufactured goods, the performance of pharmaceuticals, telecommunication products, and software was notably outstanding.[291]

[291] Pharmaceuticals (24.4) is a sub-category of Chemicals and chemical products (24). The superordinate category grew on par with the total manufacturing export figure until the turn of the millennium when it bypassed the growth rates of total exports. Pharmaceuticals, if treated in isolation, grew faster than total exports throughout the period as can be seen in figure 2.3.

Figure 2.3 Total manufacturing exports and exports of pharmaceuticals, telecommunication products, and software, 1995-2007 (volumes, 1995=100)



Source: SCB.

Of these three industries, pharmaceuticals and telecommunications together account for a significant share of total export value with software making more of a marginal contribution. In absolute terms, the three categories of machinery and equipment, motor vehicles, and telecommunications are the giants, with chemicals and iron and steel just behind them.

As discussed in the introductory chapter, the second half of the 1990s is widely considered to mark the onset of a new era; a *new economy*.[292] In short, this new era was characterized by an increasing importance of the service sector and the widespread penetration of ICT in production. The latter has had enormous social, cultural, and economic implications. The contribution of ICT to the economic performance of the country is rooted in its seemingly infinite potential to increase productivity through implementation and application.[293] The impressive performance of the

[292] See contributions in Ekonomisk Debatt 2000.

[293] Lind 2003; Johansson 2003

Swedish ICT industry (pictured to some extent in figure 2.3) has been described as being nothing short of a marvel.[294] The ancestry of the Swedish ICT industry can be traced back to Ericsson, founded in 1876. Ericsson achieved early success in telephones and telephone switchboards. In the beginning of the 1980s the firm reoriented from regular to mobile communication and in 1981 the first mobile system (NMT) was installed in Saudi Arabia.[295] The broader basis of today's ICT industry developed when firms (e.g Telelarm, Svenska Sambandscentralen, Nordiska Radiocentralen, Technophone, Spectronics, AGA-Sonab, Företagstelefon) started to enter into unregulated niches of the telecommunication market (wireless and data communication), a development that had already started in the 1960s but gained momentum gradually in tandem with increasing technological sophistication.[296] In the early days the industry was developed in close cooperation between private actors and the government agency Televerket (Swedish Telecom).[297] The fixed telephone infrastructure was a natural monopoly of Televerket's and the agency was very active in the development of technology. New telecom laws in the early 1990s, formalized in the Telecommunications Act in 1993 abolished a set of legal barriers to entry and paved the way for a host of new firms to try their luck. Not since the beginning of the twentieth century, had a single industry attracted as much investor and entrepreneurial attention as ICT experienced in the 1990s.[298] The deregulations together with the established industry infrastructure, with accumulated knowledge and prior experience on which entrants could draw on provided fertile ground for the subsequent development.[299] While Ericsson has remained the hub of the Swedish ICT industry throughout the

[294] Ekonomisk Debatt 2000; Ny Teknik 2000; Glimstedt and Zander 2003

[295] In Swedish comparison the reorientation of Ericsson came late as there were several firms already active in the mobile telephone industry (Glimstedt and Zander 2003, p. 117).

[296] Glimstedt and Zander 2003 p. 115

[297] Mölleryd 1999 ch. 5 and 6

[298] Johansson 1999b ; Glimstedt and Zander 2003 p. 128

[299] Zaring and Eriksson 2009

period small firms have become increasingly important, especially in terms of employment.[300]

By the turn of the millennium the ICT market was in a state of euphoria. The number of GSM users skyrocketed and so did the stock market value of numerous ICT firms. The Stockholm stock exchange delivered several all-time highs. The day before the lights went out (March 7 2000) the value of the stock exchange was double that of Swedish GDP and Ericsson was the highest valued firm.[301] The two first years of the new millennium were turbulent characterized by high stock market volatility. Industry giants like Ericsson, and successful startup ventures were affected alike by the bursting of the IT-bubble. Ericsson's share price held high value until 2001 when profits plummeted. Ericsson's crisis resulted in extensive job losses and the merging of terminal manufacturing in the mobile phone division with Sony.

Although the stock exchange collapse was one of the worst in history and the ICT industry was undisputedly important to the Swedish economy, the end of the ICT bubble did not inflict long-term damage on the macroeconomic performance of Sweden.[302] Swedish yearly average GDP growth rate in the new millennium has been high in comparison to the U.S., the OECD and EMU countries.[303]

2.8 Periodization

The present chapter has summarized the main traits of Swedish economic and industrial development during the twentieth century until 2007. It has aimed at the characterization of five distinct sub periods. Table 2.5 presents the periods and their key characteristics.

[300] Johansson 2003

[301] Affärsvärlden 2009

[302] Erixon 2011b p. 302

[303] Erixon 2011b p. 303-4

Table 2.5 Periodization

Sub period	GDP/capita growth rate	Characterizing features
1970-1975	2.8	International oil crisis, 'bridging over' policy, high growth, profits, and investments, tremendous real wage increase, cost increase.
1975-1982	0.6	Slow down, cost crisis, acute curbing of crisis, devaluations in 1976, 1977, 1981, and 1982, relatively low unemployment, low private investments.
1982-1990	1.9	16 percent devaluation in 1982, increasing profits and growth, stock market frenzy and commercial real estate bubble, high inflation, low unemployment.
1990-1994	-0.8	Financial crisis, corporate losses, drop in GDP, high unemployment, loss of jobs and workplaces in the manufacturing sector, high inflation, increasing trade surplus, growing export share, maintained productivity.
1994-2007	2.3	Rapid recovery, strong productivity growth, growing export share, increasing trade surplus, the IT-"wonder".

Note: GDP per capita growth rate refers to annual percentage growth rates (constant prices).
Source: Schön and Krantz 2012.

This chapter has covered the salient historical facts and has left a review of the deeper analyses of this development to the following chapter.

3. Economic performance and industrial transformation in Sweden, 1970-2007: received analyses

In the introductory chapter, it was remarked that long-term fluctuations of Swedish economic performance have attracted both domestic and international attention. The majority of accounts focus on the institutional set up and the economic policies in their analyses of these fluctuations.[304] It is beyond the scope of this thesis to offer an all-encompassing review of this literature. Rather, the scope is limited to accounts emanating from two domestic research traditions whose primary concern is the link between macroeconomic performance and the development of industry. The two traditions considered are the Swedish Growth School and the Structural Analytical Tradition.[305] Of the two, the Swedish growth school represents the dominating perspective in placing heavier emphasis on institutions and economic policy in its accounts. The structural analytical tradition offers a perspective that challenges the inferences of the Swedish growth school.

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[304] See chapter one for references to international accounts. See e.g. Lundberg (1983), Andersson et al. (1993), Tson Söderström et al. (1994), Lindbeck et al. (1994), and Jonung (1999), for examples of domestic accounts.

[305] The Swedish growth school is a denotation of contemporary times. Johansson and Karlsson (2002) were first to use the label. Eklund (2010) discusses whether the Swedish growth school is a real school or not. The author of this thesis has chosen to stick to the school label. However, the denotation shall first and foremost be regarded as rhetorical. The structural analytical tradition may be traced back to Knut Wicksell and Johan Åkerman. However, in this thesis, the denotation regards the modern development of this research tradition, represented first and foremost in the work of scholars at Lund University.

The analyses developed within these two research traditions are based on two different analytical models. However, since their origins can be traced back to common ancestry, section 3.1 deals with this parent root. Section 3.2 introduces the two research traditions and the analytical models underlying their approaches respectively. Section 3.3 exemplifies the differences in the two models in terms of their interpretations of Swedish productivity statistics 1966-2007. Section 3.4 reviews analyses produced by each of the two research traditions. The reviewed analyses deal, in a broad sense, with the themes of the research questions: the temporal pattern of transformation, the role played by firms of different sizes, and structural change in the manufacturing sector. The empirical chapters will relate the findings of the thesis to these analyses. Section 3.5 makes some concluding remarks.

3.1 A long-standing research tradition

Sweden has a long tradition of research on industrial change. The research tradition developed both in academic institutions and in research institutes with close ties to the private business sector. This explains the research culture of combining theoretical rigor and inductive theorizing, the latter drawing on historical data and case studies. Early on, skepticism was expressed towards explanations of economic and industrial change based solely upon macroeconomic variables. Scholars moved freely between macro and micro perspectives, with incessant attention paid to institutional structures. The research agenda pertained to "*changes through time within and among micro entities*".[306]

Sources of inspiration were primarily found among scholars associated with the Austrian school of economics such as Carl Menger, Ludwig von Mises, Joseph Schumpeter, Friedrich von Hayek, and among institutionalists like Thorstein Veblen.[307] Swedish ancestry in economics can be traced back to the ideas of Knut Wicksell and Johan Åkerman.[308] However, the primary

[306] Dahmén 1991a p. 137

[307] Pålsson Syll 1997; Karlsson et al. 2007; Johansson 2010

[308] Wicksell 1936 (first published in 1898); Åkerman 1928, 1939, 1944

source of inspiration to Swedish research on industrial transformation in more recent times is Erik Dahmén.[309]

3.1.1 Erik Dahmén and industrial transformation

Just like that of Joseph Schumpeter's, Erik Dahmén's research focused on the transformation of industries through creative destruction.[310] Dahmén advocated the importance of insights and the use of research methodologies from different disciplines (e.g. economic theory, statistics, economic history, and business administration) and shunned the "mathematization" of economics brought about by the cliometric revolution. Furthermore, he was disinclined to use statistical aggregates and warned of the "fallacies of aggregative thinking".[311]

Dahmén defined industrial transformation as "the introduction of new commodities, new technology, and new markets, and how these innovations struggle with, and win out over, older commodities and methods".[312] There are always two sides to Dahménian transformation: one positive and one negative. Thus, Dahmén's ideas are similar to Schumpeter's notion of creative destruction, where creation is the flipside of destruction. Whether individual firms find themselves on the positive or negative side depends on the fit between their current configuration and the environment and its development trajectory.[313] If such a fit is accomplished a firm may capitalize on the positive side, if no such fit exists, a firm will find itself on the negative side. Either way, transformation always implies pressure to act:

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[309] See Pålsson-Syll (1997) "Den strukturanalytiska traditionen" for the development of Swedish structural analysis. See Eklund (2010) for a portrait of Erik Dahmén. See Erixon (2011a) for a discussion of the parallels in Åkerman and Dahmén's work.

[310] Dahmén 1950, 1980 p. 28

[311] Dahmén 1942, 1991b p. 25ff. Quote from Dahmén (1984 p. 27).

[312] Dahmén 1950 p. 4

[313] Compare with the ideas of a fitness landscape found in Siggelkow (2001) and Levinthal (1997).

> "[a] transformation process usually has its center somewhere between two extreme situations. One of them is dominated by opportunities to generate new fields of activities and thus to contribute to a restructuring of industry and trade. If so, the transformation pressure is labeled positive. The number and importance of such opportunities and the extent to which they are seized depends i.a. on the quality of entrepreneurship as well as on "institutional" factors such as the characteristics and functioning of labor and capital markets. A situation might also be dominated by a more or less strongly felt necessity to adjust and to adapt. Here losers in a conflict between "new" and "old" things are numerous and in many industries possibly in majority, namely if the winners happen to be foreign producers. How such negative transformation pressure is handled, i.e. how efficiently the ensuing economic problems are dealt with, is likewise dependent on entrepreneurial qualities and institutional circumstances".[314]

Whereas Dahmén's ideas are similar to those of Schumpeter in some respects, they differ in others. Dahmén was preoccupied with the role of institutions to an extent that Schumpeter was not.[315] Schumpeter acknowledged the importance of properly working credit institutions but did not address institutions in a wider sense. The incorporation of institutions into the analysis of industrial transformation is thus a distinctive dimension of the Swedish research tradition.

Structural imbalances are a central concept in Dahmén's model. Such imbalances pertain to a situation where factors that drive transformation are out of tune with each other. Unresolved structural imbalances exert a depressive pressure on the economy. One may ask why such imbalances have to arise. To answer that question, Dahmén draws on the Austrian concept of *malinvestments*; the allocation of resources to commodities and methods on the negative side of transformation.[316] A pivotal part of the

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[314] Dahmén 1991a p. 138

[315] Dahmén 1950 p. 9-11, 420-421. See also Erixon 2011a. Dahmén was explicit about the influence Joseph Schumpeter exerted on his own work. Both the introduction and the conclusions in his dissertation speak expressly to Schumpeter's work (Dahmén 1950).

[316] One hypothetical example would be that a majority of large car manufacturers focus on developing and investing significant capital outlays on new gasoline engines while a breakthrough in batteries for electric cars is silently approaching. The unwillingness among the dominant players to concentrate on the new technology may put the electric car

Dahménian framework is that the flipside of the depressive pressure brought about by structural imbalances is entrepreneurial opportunities. Structural imbalances are thus also a prime expansionary force. The seizing of entrepreneurial opportunities will lead to the development of complementary technologies or institutions that will resolve the structural imbalances, release the growth potential in new innovations through synergies, and give rise to powerful blocks of development.[317] Technologies and institutions are complementary when positive externalities arise as they are aligned in a *development block*. Such development blocks, another central concept of Dahmén's, form powerful engines of economic growth.[318]

Dahmén is not entirely explicit upon whether industrial transformation is a continuous or discontinuous process. When defining industrial transformation in one of his later texts Dahmén repeatedly describes it as continuous:

> "Production methods and products are developed by firms through a continuous interaction between them, their employees, and their customers/…/the continuous renewal of production methods and products render an increase in what is referred to as *productivity*".[319]

Dahmén's theoretical anticipation was influenced by the Austrians and predicted that market forces would ensure constant transformation, competition would see to that the old was gradually replaced by the new.

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breakthrough on a type of suboptimal hold (especially as these players are also likely to have a political influence thanks to lobbying and thereby affect governmental investments). Prospect theory may explain the occurrence of malinvestments; Knightian uncertainty restricts the ability of managers, investors, and politicians to make, what in hindsight turns out to be, the right choices. See Tversky and Kahneman (1974, 1981, 1992), Kahneman and Tversky (1979), or any other work in the field of prospect theory for more on this topic.

[317] Dahmén 1984, 1991a. Conversely, if imbalances are not resolved, symptoms of a crisis may arise. A development block is defined as "a sequence of complementarities which by way of a series of structural tensions, i.e. disequilibria, may result in a balanced situation (Dahmén 1991a p. 139).

[318] Schön 2006a p. 53ff. Similar thoughts are found in Schumpeter's Theory of Economic Development (1934).

[319] Dahmén 1980 p. 28 (author's translation)

Yet, in practice transformation may be obstructed by structural imbalances. Path dependencies combined with vested interests in general and governmental intervention in particular could hold transformation back: "rigidities and delays, possibly increased by government subsidies, or by other ways of throwing good money after bad, in scrapping obsolete production capacities are bound to tie up capital and labor that could be used elsewhere in a more productive way".[320]

3.2 Bifurcation in the Dahménian lineage

During the 1970s and 1980s Swedish research on industrial and economic development bifurcated into two quite separate branches. One of them, recently called the Swedish growth school, was developed primarily by economists whereas the other, the structural analytical research tradition, was cultivated by economic historians.[321] The research agendas of these two branches of research on industrial transformation are based on two separate analytical models, which draw on different parts of Dahménian heritage and combine them with additional sources of inspiration.

3.2.1 The Swedish growth school

The Swedish growth school emerged out of the academic milieu at Industriens Utredningsinstitut (The Industrial Institute for Economic and Social Research, henceforth IUI), in particular under the leadership of Gunnar Eliasson (1976-1994).[322] The institute, once led by Dahmén (1949-

[320] Dahmén 1984 p. 31. See also Dahmén (1991b p.34-35).

[321] The author of this thesis chose to reserve the 'structural analysis' label for the relatively recent and contemporary research undertaken by economic historians primarily at Lund University. The choice does not neglect that the structural analytical tradition has a rich history and has also evolved in alternative ways to that which I choose to concentrate on here (see Pålsson Syll 1997). Considering the modern developments of the structural analytical research tradition, the thesis will henceforth refer to this simply as the "structural analytical" approach.

[322] Eliasson 1987c; Pålsson Syll 1997 p. 106; Henrekson 2008. The institute was founded in 1939 by Sveriges Industriförbund (the Foundation of Swedish Industry, SI) and Svenska

1951) had ties to the private business sector, not least in the Wallenberg sphere.[323] Eliasson was recruited to the institute in 1976 and was expected by the board to, in his own words, "bring clarity to the current turbulence in the economy and the political implications thereof."[324] The IUI board found the neglect of firms and entrepreneurs in macroeconomic explanations of the economic slowdown unsatisfactory.[325] Under the leadership of Eliasson, a model of industrial transformation inspired by Dahmén and by Austrian economics was developed at IUI. Markets, firms, entrepreneurs, and institutions are central elements in this analytical model. Markets are regarded as the most superior organizers of economic activity, economic activity comes down to the actions and behavior of individual firms, entrepreneurs are essential to reinvigorating the economy through the seizing of previously unexploited business opportunities, and finally, institutions shall be designed so as to ensure the workings of markets in order not to obstruct potential economic growth. This model was partly a conceptual framework to discuss industrial dynamics verbally, but there was also a computer based micro-macro model implemented empirically on the Swedish economy with the explicit ambition of integrating the analysis of firm behavior into development of the aggregate economy.

Arbetsgivareföreningen (the Swedish Employer's Confederation, SAF). The institute was and is a private, non-profit research organization. See volume edited by Henrekson (2009) on the development of the research institute, especially chapter 8 by Wohlin and chapter 9 by Eliasson. The Swedish name of the institute was changed to Institutet för Näringslivsforskning in 2006.

[323] Marcus Wallenberg was the honorary president of the institute until his death in 1982.

[324] Eliasson 2009 p. 137 (author's translation)

[325] Also Erik Dahmén criticized the received explanations of the economic turmoil of the 1970s. Dahmén argued that causes had to be sought not in external shocks or increasing costs during the preceding couple of years, but in an inert industrial structure whose transformation was obstructed by social and political interests, the latter which contributed to the cost increase. High costs were a symptom, not a cause. The capability to adapt to the new circumstances (e.g. increased international competition) by way of industrial transformation/structural change was thus severely reduced and contributed to the magnitude of the crisis. See Eklund (2010 p. 81-83) for an overview of Dahmén's position.

The bottom line of the explanatory model developed at IUI is that technology sets the upper boundary of productivity and economic growth.[326] The extent to which entrepreneurs and existing firms manage to seize and exploit business opportunities provided by an inexhaustible pool of technology determines the rate of growth. Recognizing, seizing, and exploiting business opportunities require firms to have capabilities of assembling and assessing information. Accordingly, a central concept in the explanatory model is *competencies*. In the model the stylized firm is a *competent team*.[327] Eliasson divided firm competencies into three levels.[328] The top level regards strategic competency. Top level competency is essential when a pressing need to change the structure of a firm arises. The intermediary level concerns the tactics employed to coordinate and control the firm through for example data management, budgets and reports. The lowest level of competency pertains to the daily operations of firms: the running of the organization in an efficient way. These various competencies and their embodiment in managers and managerial teams will guide the decisions and actions of firms. In the model, individuals are boundedly rational and their decisions and actions will thus be based on a limited amount of information.[329] Eventually, some of these decisions and actions will turn out to be successful while other will prove to be mistakes. Eliasson calls all decisions and actions to reallocate resources *business experiments* designed to be tested in markets.

In many ways, the concept of an *experimentally organized economy* represents the full model of Eliasson's and IUI: s.[330] An experimentally organized economy is characterized by widespread and intense experimentation with regard to seizing and exploitation of business opportunities, lower level decisions, and actions. An economy organized accordingly is thus

[326] Eliasson 1997 p. 203

[327] Eliasson 1990b

[328] Eliasson 1985b

[329] Eliasson 2007 p. 262-3

[330] Eliasson 1987b

continuously pushing the upper boundary set by technology (i.e. innovates and grows continuously).[331]

The market is center stage in the 'experimentally organized economy' model, it is the pre-eminent source of information, the arena where economic actors communicate, capital is transferred, and where experiments are undertaken. According to the 'experimentally organized economy' model the market is the superior selection environment, the place where obsolete structures and unsuccessful experiments are weeded out and where winning experiments are selected. The likelihood of successful experiments (i.e. the economic growth odds) becomes greater (odds are improved) as the number of actors that engage in experimentation increases.[332] Of all markets, the stock market is regarded as the most important as it brings together finance and the real economy.[333]

Whereas all decisions and actions to reallocate resources are experiments, the ultimate form of experimentation is the entry of a new innovative firm. The model states that creative destruction requires high levels of entry and the closure of unprofitable firms.[334] The theory of the 'experimentally organized economy' is skeptical regarding the ability of public bodies to select winning experiments:

> "The experimentally organized economy has two sides. The first is to select a maximum number of potential winners for trial in the market. The second side is to identify and eliminate the bad draws as rapidly as possible. The political system, of which industrial policymakers are a part, is notoriously badly-organized for accepting and correcting erroneous decisions. The anonymous market place will always be the supreme performer when it comes to closing down badly-performing production activities" [335]

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[331] Eliasson and Lindberg 1988 p. 29

[332] The model advocates market selection instead of internal firm selection (Eliasson 2007 p. 267).

[333] Eliasson and Lindberg 1988 p. 55

[334] Eliasson et al. 2005

[335] Eliasson 1987b p. 27

The disbelief in the ability of public bodies to select winning experiments is based on the assumption that individuals in public bodies, in addition to being boundedly rational, have less experience than firms in the experimenting activity they are engaged in.[336] Furthermore, public experimentation may have effects so profound that it outdoes the effects of experimentation by privately owned business firms.[337] While the experimentally organized economy is driven by firms and individuals that conduct thousands of more or less successful business experiments through creating, identifying, and commercializing new technology, governmental intervention is viewed as potentially harmful-policy experiments that are highly risky because they may dominate and destruct the entire economy.[338] Actors in a so called *competence block* are those actors that we need as a minimum to transform new technology into output growth.

Table 3.1 Actors in a competence block

Actors
Competent customers
Innovators
Entrepreneurs
Venture capitalists with industrial competence
Exit market actors
Industrialists

Source: Eliasson 2007 p. 268.

In the stylized experimentally organized economy, transformation is a continuous process: "a dynamic industry is constantly transforming as new technology, new products, and new firms are introduced and obsolete technology, old products, and underachieving firms are wiped out".[339] Experiments will appear continuously as actors align with respect to specific

[336] Örtengren 1988; Eliasson 1993b, 2007

[337] Eliasson 1987b p. 26; Eliasson and Lindberg 1988 p. 37-8

[338] Eliasson and Eliasson 1997; Eliasson 2007 p. 267-72

[339] Eliasson and Johansson 1999 p. 2, author's translation. See also Eliasson (1988a), Eliasson and Karlsson (1998), Andersson et al. (1993 p. 26), and Carlsson (2002 p. 45).

business opportunities, the exploitation of which creates temporary monopolies. Monopolies are transient as there is constant challenge from new experiments.[340]

Note that the modeling of transformation as a constantly ongoing economic process is normative. The extent to which transformation is continuous in practice is determined by whether or not markets are allowed to coordinate experimentation and whether or not policies and institutions are conducive to ensuring and promoting such coordination. As shall be seen in the narratives and analyses based upon the 'experimentally organized economy' model, continuous transformation and an institutional framework suited to achieving that end must be regarded as a modeled ideal rather than a description of reality.[341]

3.2.2 The structural analytical research tradition

Modern structural analysis was developed and cultivated by economic historians. The theoretical roots of structural analysis draw on Åkerman's idea that specific structures characterize different epochs, Gerschenkron's take on structural change as a dynamic process, and Dahmén's notion of development blocks respectively.[342] Åkerman, Gerschenkron, and Dahmén were important influences when the decision was taken to construct Swedish historical national accounts at Lund University in the 1970s. This work involved scholars such as, Olle Krantz, Carl-Axel Nilsson and Lennart Schön.[343] The historical national accounts came to be an important springboard in the development of the structural analytical framework.[344]

An early formulation of the framework was provided by Krantz and Schön in 1983.[345] Later, Krantz and Schön developed different views of the

[340] Eliasson and Lindberg 1988 p. 53-4

[341] Andersson et al. 1993 p. 26; Eliasson and Johansson 1999 p. 2; Carlsson 2002 p. 45

[342] Åkerman 1928, 1939, 1944; Gerschenkron 1962

[343] Krantz and Nilsson 1975; Krantz 1979

[344] Nilsson and Schön 1978

[345] Krantz and Schön 1983

structural development of the Swedish economy.[346] Whereas Krantz argued that the development of the 1970s and 1980s broke with the till then observed structural periodicity, Schön maintained the position that the development during these decades contained the traits suggested by the structural periodization.[347] This thesis draws on Schön's description of the 1970s, 1980s, and the ensuing decades.

In particular, modern structural analysis is based on the Dahménian concepts of development blocks and complementarities. In comparison to the deductive and normative theorizing underlying the 'experimentally organized economy' model, the structural analysis model is based on inductive, appreciative theorizing. Furthermore, there is an ontological difference between the Swedish growth school and the structural analytical approach. In contrast to the Swedish growth school model, structural analysis proposes that transformation is, by its very nature, *discontinuous*.[348] The basis of the structural analytical model is that two distinctive types of investment behavior guide industrial development; investments aiming at increased efficiency of current structures and those destined for the renewal of structures.[349] The discontinuous nature of transformation is characterized by shifts in the aggregate between these two investment types.

On the micro level the difference between the two types of behavior refers to whether the firm should concentrate resources in the exploitation of current products or processes (e.g. increasing profit through cutting production costs) or whether it should pursue the exploration of new products and processes. At the macro level, higher levels of investments in efficiency or alternatively in renewal identify either periods of rationalization or transformation of industrial and societal structures respectively. Rationalization may increase productivity and economic growth in the short run through the reallocation of resources (e.g. through cutting costs or closure of inefficient or obsolete plant) but it does not alter the industrial

[346] Schön 1993a, b; Krantz 1993

[347] See Edvinsson (2010) for a recapitulation of the debate.

[348] Krantz and Schön 1983

[349] Krantz and Nilsson 1975; Krantz and Schön 1983; Schön 1990 p. 14-5, 2006a p. 19-22

structure or improve the long-term growth prospect.[350] Transformation through innovation, on the other hand, leads to a structural change of the industrial landscape and is a prerequisite for long-term economic viability.[351]

According to representatives of the structural analytical research tradition, various indicators of economic activity (e.g. investment ratios, the export to production ratio, profit shares) show that investments shift in character between rationalization and transformation purposes in a cyclical manner.[352] The model is based upon aggregate empirical patterns of alterations between long periods during which investments lead to gradual technological change and short-term productivity increase and periods during which investments are far-sighted and productivity growth is meager as firms are preoccupied with the searching for and development of new products and processes.[353]

These so called transformation and rationalization periods exhibit different dynamics. A structural crisis, fed by increased international competition and falling demand, marks the beginning of a transformation period.[354] Such a period is characterized by longstanding processes in which emerging structures come to replace established ones, the latter whose growth potential has been exhausted. Typically, these emerging structures revolve around the exploration of new technologies.[355] Existing and newly established firms rush in to seize and create new business opportunities based upon these new technologies and firms whose configuration (e.g. activities) does not fit with the development of the environment (i.e. the increased competition) see profits falling. These are the positive and negative expressions of transformation pressure.

Transformation processes are creative struggles; inertia holds development back while new opportunities push it forward. At the level of the firm, reshaping a finely-tuned organization focused on efficient production of

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[350] Schön 1990 p. 14

[351] Schön 2006a p. 77-83

[352] Krantz and Schön 1983; Schön 1982b, 2006a p. 72-7

[353] Schön 2006a p. 20-1

[354] Schön 2006a p. 74-7

[355] Krantz and Schön 1983; Schön 2006a p. 77ff

refined products is typically a feat not accomplished without investing sufficient time to allow for appropriate analysis and decision making to occur. At the level of society, factors such as institutions, policy, infrastructure, employment, labor market relations are fashioned to facilitate the workings of current structures and allow for gradual improvement.[356] Transformation pressure upsets those mechanisms of socio-economic efficiency. Countervailing forces arise that benefit old structures and disfavor new ones.[357] It may for example become obvious that institutions are not designed to facilitate new firm entry. As the number of entrepreneurs wishing to exploit new business opportunities increases, destruction of older structures is inevitable.

The all-encompassing nature of transformation processes tends to render them prone to bottlenecks.[358] Gradually, as search progresses and actors move up the learning curve, bottlenecks are resolved and new structural alignments are formed, in and between firms, industries, and society. Such alignments see complementarities between different factors and constitute the so called (Dahménian) *development blocks*. As part of the maturation of the new production structure, downward price pressure sets in and dominant designs and standards emerge.[359] In this process, inefficient actors will expire. This process reaches its climax in a so called transformation crisis; an intensified filtration period characterized by the shaking out of firms active in new as well as old industries.[360] Such a crisis is the peak of creative destruction.

The ensuing years see transformation culminate, new structures mature, mass production of new technologies, changes in investment behavior, and the growth potential embodied in the new structures and technology

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[356] Krantz and Schön 1983; Schön 2006a (ch. 4)

[357] Schön 1982b

[358] The development of electric cars is a case in point. Bottlenecks could include to the development of batteries, as well as an immature battery charging station infrastructure.

[359] For the striking resemblance with the industry and product life cycle literatures, see e.g. Utterback and Abernathy (1975), Klepper and Graddy (1990), Utterback and Suárez (1993), Klepper and Miller (1995), and Klepper (1997).

[360] Schön 2006a p. 82-5

become realized.[361] This is a so called 'rationalization period'. Competition continues to increase, profit opportunities are exhausted, and efforts to rationalize production (e.g. through mergers and acquisitions, economies of scale etc.) intensify. This increased competition again places a downward pressure upon prices, decreases profit margins, and impairs resistance to negative demand shocks. In sum, the economy becomes more susceptible to structural crisis.

The successive periods of 'transformation' and 'rationalization' constitute a pattern of so called *structural cycles* in which the period studied in this thesis comprises approximately the duration of one such cycle. The second half of the 1970s is thus considered a structural crisis, the 1980s is viewed as a period of transformation, the financial crisis in the early 1990s as a transformation crisis, and the rest of the period increasingly characterized by rationalization.[362]

3.3 The central contestation

The two analytical models that have been presented have arrived at quite different conclusions when it comes to the association between micro and macro level development during the period studied in this thesis. Thus far, analyses have relied on surveys, case studies, and economic indicators such as GDP, investment ratios, productivity statistics, and R&D expenditures. The interpretation of the productivity statistics in table 3.2 exemplifies the differing inferences. This difference pertains to whether the dismal productivity growth experienced between 1975 and 1990 reflects slow or intense transformation.

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[361] A considerable lag (often of more than 15 years) between transformation and productivity increase is a rule rather than an exception (Schön 1990 p. 93). See also David (1990), Hornstein and Krussell (1996), Greenwood and Yorukoglu (1997) on innovation-productivity lags.

[362] Schön 1982a, 2000, 2006a

Table 3.2 Labor productivity growth rates in the Swedish manufacturing sector, 1961-2007 (percent, period averages)

Year	Growth rate
1961-1970	6.7
1970-1975	4.2
1975-1982	1.9
1982-1990	2.4
1990-1994	4.5
1994-2007	7.0

Note: The table concerns labor productivity in terms of output per hour worked. Source: the U.S. Bureau of Labor Statistics, author's own calculations.

According to the Swedish growth school the meager productivity growth is a sign of particularly slow-paced transformation.[363] Crisis policy and unfit institutions are claimed to have mitigated transformation pressure so much as to slow down restructuring.[364] The recovery of the 1980s is therefore not a true recovery but a result of short-term adaption and high profits enabled by the devaluations in the beginning of the decade.[365] Representatives of the Swedish growth school note that "[t]he process of creative destruction is stifled".[366] The gradual shift in the evolution of policy during the 1980s and the major reorientations thereof during and after the 1990s crisis is argued to have set the forces of transformation free.[367] The positive productivity experience from that point is thus a reflection of an increased pace of adaptation and restructuring.[368]

According to the structural analytical narrative, slow productivity growth occurring between 1975 and 1990 signifies intense transformation: "[t]he

[363] Erixon 1991

[364] Eliasson and Carlsson 1979; Erixon 1989; Eliasson 1993a, 1993b, p. 89-106; Andersson et al. 1993 (ch. 1)

[365] Eliasson 1999 p. 52

[366] Henrekson et al. 1996 p. 279

[367] Edquist and Henrekson 2013

[368] Davis and Henrekson 1999

weakening of industry's productivity growth that began in the mid-1970s is often seen as an ingredient of the Swedish decline. However such a trend during a transformation period is not an unambiguous sign of negative development or inadequate change. It may be an indication that new production systems, knowledge and products are being tested and cultivated more than before/…/Rapid transformation may be associated with weaker productivity growth, which accelerates when transformation starts to slow down".[369] Further, as "[r]enewal and transformation are time-consuming investments in the future, the concepts of growth and productivity are unwieldy yardsticks of success during transformation period".[370] It is argued that the restructuring of Swedish industries was exceptional by international comparison, both in terms of magnitude and speed.[371] The increasing productivity growth which was recorded after 1990 is in this case interpreted as a sign of waning transformation and the realization of growth potential in new, mature, structures. The growth is both a direct and indirect result of investments in renewal that were made in the two preceding decades. Advances in learning processes, diffusion, incremental innovations, and complementarities enabled growth based on the new technology to take off. The remainder of this chapter is dedicated to a review of narratives and analyses produced by the two research traditions concerning the period of study.

3.4 Analyses of Swedish industrial transformation between 1970 and 2007

The analyses reviewed in subsections 3.4.1 through 3.4.3 address the temporal pattern of transformation, the role played by firms of different sizes, and structural change in the manufacturing sector. The reviews are set up so as to thematically correspond to the three research questions posed in the introductory chapter and summarized in table 3.3.

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[369] Schön 2012 p. 328

[370] Ibid.

[371] Schön 2000 p. 492

Table 3.3 Research questions

RQ#	Research question
RQ1	Was there a key period of innovation and if so, when did it occur?
RQ2	Did firms of all sizes innovate to the same extent during the period?
RQ3	Was there an observable key period of change in structural composition of innovation output and if so, when did it take place?

All the reviewed accounts are based on one of the two models that have been described. Gunnar Eliasson is the central figure of the Swedish growth school. The majority of other contributors within this school of thought generally is or has been affiliated with Industriens Utredningsinstitut (IUI). Some researchers made contributions when the Institute was led by Eliasson (1976-1994), others when it was led by Ulf Jakobsson (1994-2005) and current scholars continue the tradition under Magnus Henrekson (2005-).[372] Other analysts with no direct formal affiliation with IUI have worked in the same tradition (e.g. Davidsson and Erixon). Several of the authors cited (e.g. Henrekson, Carlsson, Davidsson, and Johansson) contributed to the publication *Den svenska tillväxtskolan. Om den ekonomiska utvecklingens kreativa förstörelse* (2002), edited by Dan Johansson and Nils Karlsson.

Members of the "rival" structural analytical research tradition are fewer in number than those writing in the Swedish growth school tradition. Olle Krantz, Carl-Axel Nilsson, and Lennart Schön were leading figures composing early elaborations of this branch of Dahménian-inspired research. The structural analytical perspective has later been applied by other economic historians in Lund, and by economic geographers at the same university.[373] With regard to structural analytical narratives describing the period covered in this thesis, Schön is the primary contributor.

The following reviews take their point of departure from Swedish growth school contributions. Thereafter, the perspective of the structural analysis tradition is reviewed.

[372] After 2006 Instutitet för Näringslivsforskning.

[373] See for example Ljungberg (1990), Svensson (2004, 2008) Lundquist and Olander (2001, 2007) and Svensson Henning (2009).

3.4.1 The temporal pattern of transformation: the Swedish growth school perspective

Swedish growth school analyses of economic performance and the rate of industrial transformation in the 1970s and 1980s revolve around economic policies, institutions, and weak transformation pressure.[374] The analyses address both the domestic political situation prior to the international slowdown, the bridging-over policy, and the manner in which the structural problems were tackled.

Representatives of the Swedish growth school argue that the Swedish economy continued to grow in the final years of the 1960s and into the 1970s not *because* of the Swedish model, but *in spite* of it. A leftist bent of Social Democratic policy towards the end of the 1960s is argued to have resulted in inflexibility, rigidity, and structural inertia.[375] Increasingly, the Social Democratic party came to prioritize welfare expansion, redistribution, and equality instead of industrial renewal and restructuring.[376] Full employment was viewed as indispensable and thus received greater focus than the reallocation of labor to more productive activities, the latter being one of the central tenets of the Swedish model. The welfare apparatus was expanded on a broad basis. Public sector expansion killed two birds with one stone; it achieved the high welfare ambitions of the party, and it provided an opportunity to absorb redundant labor.[377] In becoming the employer of last resort, the expanding public sector made for a less flexible labor force.

The leftist bent of the Social Democratic party empowered the unions. Significant regulation of the labor market and work place conditions altered the relations between the parties (unions and employer organizations). Unions became more aggressive in the collective bargaining processes and wages increased to an extent that exceeded the moderation implied by the

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[374] Eliasson and Carlsson 1979; Eliasson 1993a; 1993b 89-106; Andersson et al. 1993 (ch. 1)

[375] Andersson et al. 1993 p. 14

[376] Henrekson et al. 1996 p. 248

[377] Henrekson et al. 1996 p. 254

original Swedish model.[378] The Swedish growth school argues that taken together, these developments violated the foundations of the earlier formulation of the model. The abandonment of its central tenets was unfortunate and did not set the Swedish economy up with the competitive structure needed to meet international challenges.[379]

The decision to increase the taxation of capital income was another left turn taken by the Social Democratic party. Together with the corporate tax system, which favored reinvestments (through the investment fund system) over dividends, representatives of the Swedish growth school argue that this higher tax on capital obstructed the proper working of the stock market, the most important arena for reallocation of capital to new experiments.[380] The regulation of the credit market and the absence of a mature venture capital market made the experimentation climate even harsher.[381]

Criticism of crisis-policy can be summarized into three points. These three points reduced pressure on Swedish firms and industries to transform during the 1980s.

First, extensive governmental support to industries such as iron and steel and shipbuilding (the so called 'bridge-over policy') is heavily criticized. Firms had little incentive to reconfigure their activities due to extensive government support of crisis-hit industries justified and complemented by the states drive for full employment.[382] Furthermore, it diverted resources from other policy initiatives, such as for example simplifying and fostering the startup of new firms. Moreover, wage subsidies to crisis-hit firms forced other non-subsidized firms to offer wages as high as those in subsidized firms and thus profitability was also impaired in firms on the positive side of the transformation process.[383] Altogether, the criticism of 'the bridge-over policy' suggests that it was a major obstruction to the reallocation of

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[378] Eliasson and Ysander 1983

[379] Eliasson and Carlsson 1979

[380] Eliasson and Lindberg 1988

[381] Eliasson 2005 p. 199ff

[382] Jakobsson and Wohlin 1980 p. 251

[383] Eliasson and Lindberg 1988 p. 37-8

production factors, in terms of both labor and capital. The actions deployed to counteract the crisis and the attempt at restructuring described in chapter two were, according to the Swedish growth school, prime examples of how to throw good money after bad.[384] The said "artificial respiration" raised barriers to entry and misaligned the competitive landscape. The 'new' is argued to have been effectively counteracted by measures to save the 'old'.[385]

The second, and related, point of criticism towards crisis policy concerns the continued expansion of the public sector. As a result of such extension, even more resources bypassed entrepreneurship policy and the incentive to create jobs (e.g. through self-employment) in the private sector was further reduced.[386]

The third point of criticism concerns the repeated devaluations, which are argued to have rendered established firms (and entire industries) less prone to reconfigure as current products became more attractive on foreign markets. Indeed, it is argued that a *revaluation* would have been the better monetary policy action.[387] According to this line of reasoning, a revaluation would have increased the transformation pressure on crisis-hit firms and industries and in so doing catalyzed quicker structural change. Instead, the need for an appreciation of the currency was disregarded and structural transformation was hampered.[388] In addition to having led to inflated firm profits in obsolete industries, the devaluations are argued to have decreased incentives to innovate and to have stifled investments in research and development in new potentially growth inducing areas. It is argued that although R&D expenditures increased significantly, only a limited number of truly novel innovations were commercialized.[389]

The recovery of the GDP growth rate in the 1980s is not regarded as a result of long-term renewal. Rather, the recovery is ascribed to short-run cost

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[384] Eliasson and Lindberg 1988

[385] Eliasson and Lindberg 1981

[386] Henrekson et al. 1996 p. 266

[387] Eliasson and Lindberg 1988

[388] Henrekson 1991; Jakobsson 1997

[389] Andersson 1993 p. 73

advantages, the international upturn, and increased flexibility and short-term adaptability in the manufacturing sector.[390] Other factors facilitating increased circulation of capital in the 1980s included a low interest rate, a failure to stick to the tight monetary and fiscal policy advocated in relation to the devaluation in 1982, and liberalization reforms of the tax system and the credit market.[391] Public expenditure increased during the second half of the decade and both price and wage inflation resulted. Wage drift contributed to low domestic productivity and an increasing volume of investments abroad.[392]

According to representatives of the Swedish growth school the severe financial crisis in the early 1990s was caused by a combination of macroeconomic shocks and chronic, structural problems that had been concealed by policy for decades.[393] The crisis was a belated acid test. The shakeout of unprofitable firms together with the gradual reorientation of policy in the 1980s and the intense reorientation thereof during and after the crisis made for more rapid transformation in the period thereafter.[394]

3.4.1.1 Turning the tables: the structural analytical perspective

Structural analytical analyses of the slow growth experienced during the second half of the 1970s and early 1980s downplay the role of policy.[395] Rather, the downturn is taken to be part of the cyclical variation between periods of slow and intensive growth found to characterize industrial capitalism in Sweden.[396] In the periodization offered by structural analysis, the period from approximately 1975 to 1995 is one of transformation. As was seen above, a central idea of this research tradition is that slow growth is a defining feature and an unavoidable 'cost' of transformation. Investments

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[390] Eliasson 1999 p. 52

[391] Henrekson et al. 1996 p. 255

[392] Andersson 1993; Andersson et al. 1993 p. 27-8

[393] Andersson et al. 1993

[394] Davis and Henrekson 1999; Edquist and Henrekson 2013

[395] Schön 1984, 1985

[396] Krantz and Schön 1983; Schön 1990 p. 2-3

are geared at long-term renewal rather than short-term efficiency and productivity. The slowdown is thus a natural trait of the cyclical development of Swedish economic and industrial structures. Nonetheless, it is inferred that policy and institutions exercise a sizeable influence on the development of the manufacturing industry in this period. According to the structural analytical narrative, policies and institutions are closely linked to the cyclical pattern. Compatibility between policy, institutions and the prevailing structure improves in periods of rationalization.[397] The strong economic growth of the 1950s and 1960s was spurred by such alignment. Fine-tuned policy, designed to engender productivity growth based on powerful and elaborate development blocks may be less suited to promoting new technologies and firms. Vested interests and collusion are some of the factors that obstruct optimal policy design, the nature of which ideally accommodates renewal.[398] Thus, when crisis set in in 1975 existing policy elements served the preservation of current structures and discouraged the formation of new ones (e.g. through the founding of new firms). In particular, both the tax system and regulated credit market were elements of the Swedish model which contributed to structural inertia.[399] On the other hand, the possibility that consensus policy and political commitment to economic growth enabled particularly rapid restructuring of crisis-exposed industries is discussed.[400] The Swedish model was thus neither unambiguously positive nor negative with regard to industrial restructuring.

While the Swedish growth school point at adjustment difficulties in crisis-exposed industries, representatives of the structural analytical perspective picture a remarkably rapid restructuring of these heavy industries.[401] Representatives of this latter perspective argue that crisis management in crisis-exposed industries fares well by international comparison.[402] The supposition that governmental support of the crisis-ridden industries

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[397] Schön 2000 p. 473-4, 486-8

[398] Schön 1982b; Krantz and Schön 1983; Schön 2000 p. 488

[399] Schön 2000 p. 486-8

[400] Schön 2000 p. 486-8

[401] Schön 2000 p. 490, 1990 p. 104-8, Ljungberg 2005

[402] Schön 2000 p. 493; Ljungberg 2005

hampered the restructuring thereof as suggested by the Swedish growth school is thus questioned by the structural analytical perspective which is more positive about the extent and speed with which industries on the negative side of transformation were restructured.[403] According to this perspective, the restructuring process was characterized by closures and concentration as well as process development and product specialization.[404]

The two research traditions diverge not only when it comes to the assessment of renewal in industries on the negative side of transformation but also when it comes to activity on the positive side. Whereas representatives of the Swedish growth school view the 1970s and 1980s as decades when creativity, innovation, and entrepreneurship were obstructed by the political and institutional environment, scholars representing the structural analytical tradition highlight the increased level of investments in R&D and the commercial breakthrough of new technologies, in particular microelectronics.[405] The period between 1975 and approximately the mid-1990s is regarded as a long cycle of investment in the buildup of an entirely new industrial structure.[406] The much contested devaluation of 1982 and the credit expansion that came about in the second half of the 1980s provided both established and new firms with opportunities to invest and the closing years of the 1980s experienced increased competition and reallocation of resources.[407] Creative destruction reached unforeseen levels of intensity in the crisis of the early 1990s during which unprofitable firms either shut down or reduced production and employment radically. In the terminology of the structural analytical perspective, the crisis was one of *transformation*. Hence while according to the narrative of the Swedish growth school, the 1990s crisis marks the beginning of a period of more rapid transformation, from the viewpoint of the structural analytical perspective this crisis signifies the start of a period of maturation of technologies and structures that were developed during the preceding ten to

[403] Schön 1990 p. 91-2; 2000 p. 493

[404] Schön 1990 p. 104-8; 2000 p. 490

[405] Schön 2000 p. 511-4

[406] Schön 2000 p. 508

[407] Schön 2000 p. 510

fifteen-year-long so called 'transformation period'. The remainder of the period is then increasingly characterized by efficiency-seeking investments rather than investments in innovation. The strong growth experienced in this period is both directly and indirectly linked to the surge of investment in renewal that took place in the 1980s. The result of these investments, in particularly those in ICT, took time to materialize as it was dependent on human capital formation, diffusion, both incremental and complementary innovations, and the development of fertile institutional and infrastructural conditions. In the second half of the 1990s, those conditions were in place and growth could take off.

3.4.2 Firms and transformation: the Swedish growth school perspective

The *experimentally organized economy* constantly evolves as new firms are born, existing firms are liquidated, small firms grow large, large firms contract, and/or firms merge and dissolve in an evolutionary manner.[408] In this model, high levels of both entry and exit are central to the viability of an economy. Renewal of existing firms and the entry of new firms are *experiments* that enhance viability by combining production factors in novel ways.[409]

The development of the Swedish firm population as observed at least up until the 1990s crisis is argued by the Swedish growth school not to resonate with the ideal picture sketched above.[410] Large multinational firms, the majority of them founded before the World Wars, became increasingly dominant in the post-war period.[411] In 1986 more than 60 percent of total manufacturing employment was located in large firms.[412] In 1991 no other

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[408] Örtengren 1985 p. 108; Eliasson 1987a, b; Henrekson and Johansson 2010

[409] Eliasson 1991b. See also Johansson (2000).

[410] Carlsson 1992b; Braunerhjelm and Carlsson 1993

[411] Eliasson 1985a; Jagrén 1988; Swedenborg 1992. Tetra Pak, founded in 1950 is an exception.

[412] Henrekson 1996 p. 37

country in the world had more Fortune 500 firms per GDP unit than Sweden.[413] Nor did any other country, at that same time, have as many large firms (500+) firms per million inhabitants as Sweden.[414] Furthermore, large firms were the primary exporters and investors in R&D. Indeed, on the whole large firms were of the most fundamental importance to the Swedish economy. Through continuous survival, the large, old multinationals have displayed persistence in innovation and an ability to resolve the productivity dilemma quite effectively; to balance off the exploitation of present resources against the exploration of new ones. One strategy to resolve this dilemma is through the acquisition of small innovative firms, a strategy adopted by large Swedish firms during the 1980s in particular.[415] Another way to achieve this balancing act is by internal re-organization through the restructuring of production, a strategy attempted successfully by a significant share of large Swedish multinationals who escaped acute crises in the late 1970s and early 1980s.[416]

The Swedish growth school turns to policy and institutions, in particular the tax system and the capital market, to explain the dominance of large firms.[417] In sum, the tax system and the credit market encouraged re-investment, favored debt-financing, and discouraged new issuance, all of which favored the nature of large established firms.[418] The investment funds accumulated capital in large firms and banks were typically more willing to lend money to those than to small and medium-sized firms (especially since banks were also influential owners and institutional ownership was favored).[419] Moreover, the corporatist element of the Swedish economy, which in pursuit of full and stable employment implied close relations between the parties of the labor market, is argued to have favored large firms rather than small and new firms.

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[413] Jagrén 1993 p. 80

[414] Henrekson and Jakobsson 2000 p. 17

[415] Jagrén 1988, 1993 p. 83

[416] Eliasson and Lindberg 1985 p. 80

[417] Eliasson and Lindberg 1988; Jakobsson 1999; Henrekson and Jakobsson 2000

[418] Henrekson 1996 ch. 4; Henrekson and Jakobsson 2000; Henrekson 2001

[419] Örtengren 1985 p. 116-8; Henrekson 1996 ch.4, pp. 76-7

The Swedish growth school considers the entry of new firms and the growth of small firms crucial to the long term viability of national competitiveness.[420] The centrality of a vital, innovative, and experimenting entrant group capable of continuously driving industrial renewal is underlined.[421] Given the preoccupation with entrants, a declining rate of startup firms in the 1960s and 1970s is considered one of the factors that could explain the poor renewal of the manufacturing industry in these decades and the 1980s.[422] While recongnizing that startup activity intensifies during the second half of the 1980s, Swedish growth school representatives argue that it is still insufficient and that few of the startups in the 1980s can be classified as manufacturing firms.[423] In addition, it is remarked that hightech startups were scarce.[424] Furthermore, several of the Swedish growth school representatives observe that the majority of small, already established firms grew slowly or not at all during the period.[425] All in all, startup activity is regarded to have been insufficient in the 1980s.

The explanations of poor startup activity and slow growth rates of small firms in the 1970s and 1980s are identical to those used to explain the relative success of large firms. The tax system and the regulated credit market discriminated against startups and small firms but have been relatively favourable to the large firms.[426] It is pointed out that new and small firms have less assets to use as collateral and are thus disfavored by a system in which banks are the primary source of finance.[427] Furthermore, small firms are likely to have less well established relationships with banks and small firm investment may therefore be considered paricularly risky.

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[420] Eliasson 1987a; 1987b; 1991a; Braunerhjelm and Carlsson 1993; Davidsson and Henrekson 2002; Henrekson 2003. See Johansson (2002) about the role of small firms and the rise of small-firm research.

[421] Braunerhjelm 1993 p. 102

[422] Du Rietz 1975, 1980; Braunherhjelm and Carlsson 1993

[423] Braunerhjelm and Carlsson 1993

[424] Örtengren 1985 p. 114

[425] Braunerhjelm 1993 p. 277; Henrekson and Johansson 1999a, 1999b

[426] Henrekson 1996 ch. 4 and 5

[427] Braunerhjelm 1993 p. 108, 112f ; Henrekson 1996 p. 61

High statutory tax rates on personal income inhibited private wealth formation and thus hindered self-employment, private ownership, and business angel activities.[428]

Small firms are not the only segment of the firm population considered to show weakness during the period. It is also observed that medium-sized manufacturing firms grew poorly between the end of the 1960s and the criris in the early 1990s.[429] The poor growth record of medium-sized firms has received a significant amount of attention as the growth of such firms is assumed to be an important source of new employment.[430] In the 1990s the size distribution of the firm population was likened to a wasp with a tiny waist; between small and very large firms, very little was found.[431] This 'wasp waist' is argued to have been a consequence of the same disadvantageous circumstances that presented themselves to small and startup firms.

The 1990s crisis marked a shift in the development of the population of Swedish manufacturing firms. The path trajectory thereafter breaks with the tendencies outlined above.[432] The Swedish growth school places a great deal of emphasis on the role of the tax reform of 1990/1991 as a decisive factor behind this trend break.[433] The reform aimed to neutralize the tax system by decreasing its distorting effects without taking away the leveling.[434] Alternative explanations of post 1990s crisis development center upon the deregulated credit market, private wealth accumulation, a decentralization of

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[428] Henrekson and Jakobsson 2000

[429] Henrekson and Johansson 1997, 1999a

[430] Henrekson 1996

[431] Henrekson 1996; Henrekson and Johansson 1997; Lodin 1999. The metaphor used in the Swedish literature is more often that of the "snapsglas" but due to poor translatability the "wasp waist" has come to serve as a substitute in the English literature. See Henrekson (1996) and Lodin (1999) for a discussion of the existence of a wasp waist and Henrekson and Johansson (1999) for an international comparison.

[432] Henrekson et al. 2012

[433] Du Rietz and Johansson 2003

[434] Davidsson and Henrekson 2002

wage bargaining, labor market deregulations, and the general deregulation of formerly controlled markets.[435]

In combination, large firm dominance, insufficient entry, and the meager growth of small and medium-sized firms in the 1970s and 1980s diminished long-run growth prospects.[436] The 1990s crisis is considered somewhat of a break and the beginning of a development more in harmony with the 'experimentally organized economy' model.[437]

3.4.2.1 Vigorous renewal and entry in the 1980s: the structural analytical perspective

Representatives of the structural analytical perspective do not reject the picture of the structure of the firm population as it is given by Swedish growth school. Neither is there any major difference regarding the causes of large firm dominance and the failure of small and medium-sized firms to grow large.[438] Rather, the two schools differ when it comes to the implications thereof. Whereas the Swedish growth school contends that the firm population structure during the 1970s and 1980s blocked forces of renewal, representatives of the structural analytical perspective argue that this structure allowed for radical transformation. The difference boils down to the extent that large firms on the negative side of transformation managed to radically reorganize themselves during the 1970s and 1980s and to the extent that new firm entry was sufficient to ensure reinvigoration of the manufacturing sector. It is argued that firms in crisis-ridden industries such as steel, pulp, and shipbuilding were restructured rapidly, not only through mergers, closures, and reductions of employment, but also through process development and product specialization.[439] This picture of large firms on the

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[435] Davidsson and Henrekson 2002; Erixon 2011b; Edquist and Henrekson 2013

[436] Eliasson 1991a; Braunerhjelm 1993 p. 91-3; Braunerhjelm and Carlsson 1993; Braunerhjelm et al. 2010. In particular, the increasing internationalization and specialization of large firms during the 1980s is argued to make the economy less heterogeneous and therefore more vulnerable, especially since new firm formation was insufficient to breed structural diversity "from below" (Andersson et al. 1993 p. 29; Braunerhjelm 1993).

[437] Edquist and Henrekson 2013

[438] Schön 2000 p. 473-4, 487

[439] Schön 1990 p. 93, 105-8, 2000 p. 490

negative side of transformation is largely rejected by the Swedish growth school. The description of the development of large firms on the positive side of transformation is similar to that given by the Swedish growth school. The 1970s and 1980s are described as a period during which formerly successful Swedish producers of for example electronics and pharmaceuticals learnt about progress and implications relating to microelectronics and biochemistry and undertook fundamental reorientations of their businesses.[440] High levels of R&D expenditure among large firms indicate large investments in new technologies and practices.

The abandonment of credit market regulations in the mid-1980s is argued to have paved the way for increased startup activity, especially in industries on the positive side of transformation and the heterogeneous category of private services.[441] According to representatives of the structural analytical research tradition, the end of the 1980s was largely a period which featured intensified reallocation of resources to new activities, a process in which new firms played an increasingly important role.[442]

As with the events of the crisis in the early 1990s, the interpretation of what transpired does not differ meaningfully from Swedish growth school analyses.[443] Crisis experienced among large firms led to reallocated labor migrating to small and medium-sized firms. Although there is no apparent role of startup firms during rationalization periods in the stylized structural analytical model, this narrative recognizes that new technology and related practices enable reorganization of industrial structures (e.g. the industrial firm population), one example of which is vertical disintegration and a resulting new role of small firms.

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[440] Schön 2000 p. 512-4

[441] Schön 2000 p. 475-8, 512

[442] Schön 2000 p. 510

[443] I.e. intense cuts and shakeout of primarily large firms (Davidsson et al. 1996).

3.4.3 Structural change in the manufacturing sector: the Swedish growth school perspective

The slowdown of the 1970s, diminishing demand, and increasing production costs led researchers within the Swedish growth school to insist on the need for far reaching structural change.[444] The Dahménian framework suggested that the weakening of comparative advantage in capital and labor intensive industries was to exert strong transformation pressure on the industrial structure. Swedish growth school representatives thus expected an industrial orientation away from such industries towards knowledge and R&D intensive industries such as pharmaceuticals, computers, telecom etc. Increased investments in R&D and a compressed wage structure (that made engineers and other highly educated personnel cheap in international comparison) were assumed to support this projected development.[445] As was seen in chapter two, industrial development followed this trajectory during the 1970s and early 1980s, as specialization in durable consumer goods, investments goods, and other consumer and input goods increased.[446] However, the development came to a halt in the mid-1980s and was reversed during the second half of the decade. The weak development of knowledge and R&D intensive exports together with the slow-changing structure of employment led Swedish growth school representatives to contend that there was structural lock-in in the 1970s and 1980s.[447] Proposed reasons for the lock-in have already been presented and relate, in short, to the institutional environment, large firm dominance, and insufficient entry and small firm growth.

Still, Swedish growth school accounts are not entirely skeptical about the extent of renewal activities taking place within the Swedish manufacturing sector during the 1970s and 1980s. It is noted that with the exception of the crisis-hit industries, large firms managed to renew and adapt to changes in

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[444] Particularly so in the apparel, textile, steel, shipbuilding, pulp, and paper industries. See for example Eliasson et al. (1979).

[445] See Carlsson et al. (1979 p. 102).

[446] Ohlsson and Vinell 1987 p. 87-9; Ohlsson 1992 p. 31; Hansson and Lundberg 1995 p. 85

[447] Andersson et al. 1993; Jagrén 1993 p. 83-4; Andersson 1994

the competitive environment through reorganization and changes in the structure of production.[448] Furthermore, an increasing degree of startup activity and small-scale success in niches of fine chemicals and pharmaceuticals is highlighted.[449] Also, some of the up-and-coming firms of the 1980s are discussed.[450] Those are successful firms which could break into the large-firm category. Instead, the skepticism of the Swedish growth school regards the extent to which these signs of adaption are sufficient to change the structure of the Swedish manufacturing sector in the long term. Small firms are shown to be unwilling to expand, up-and-coming firms number only a handful, the extent of startup activity is not satisfactory, and already large firms may fail to undertake requisite transformations in the future.[451]

When looking back at the 1970s and the first half of the 1980s, Swedish growth school accounts note a shift from machinery-intense to information-intense production, a significant part of which occurs in services.[452] However, writings occurring in the beginning of the 1990s mention the reversal of specialization in R&D and knowledge intense products during the second half of the 1980s.[453] It is argued that Swedish manufacturing became less innovative from approximately the mid-1980s.[454] Physical structures are claimed to have become less flexible whereas short-term adaptability through for example the adjustment of production flows is claimed to have improved due to increasing use of information and communication technologies.[455]

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[448] Eliasson and Lindberg 1988 p. 86

[449] Eliasson and Lindberg 1985 p. 83

[450] Jagrén 1988 p. 278-9

[451] Eliasson and Lindberg 1985 p. 83; Pousette 1985 p. 195-7; Jagrén 1988 p. 278-9

[452] Eliasson and Lindberg 1985 p. 103

[453] Jagrén 1993 p. 84

[454] Eliasson 1999 p. 52

[455] Eliasson 1999 p. 52

In the 1990s and 2000s, ICT account for the dynamism in the manufacturing sector.[456] The growth of ICT industries was particularly strong in the 1990s.[457] The ICT industry employed an increasing number of people and it supplied technology that made more flexible and efficient production possible. It is shown that ICT industries (in particular radio, television, communication equipment, instruments, and software) have experienced a marked increase in numbers employed.[458] Furthermore, it is shown that rates of both entry and exit are high in ICT industries exemplifying aggressive experimentation and dynamism.[459] The creation of new jobs in these industries is largely explained by small firm growth and the entry of new firms. Several institutional changes are suggested to explain this: the deregulation of product markets (in particular the telecom market in 1993), the easing of tenure-priority rules in 1997, increased decentralization of wage bargaining, and tax reforms.[460] In general, representatives of the Swedish growth school refer to the financial crisis in the early 1990s as an institutional watershed that paved the way for structural change in a wide sense (e.g. with regard to employment, industry structure etc.).[461]

3.4.3.1 Intense structural change in the 1980s: the structural analytical perspective

The structural analytical perspective describes the period 1975-1995 as one of intense structural change in the manufacturing sector. The increase in R&D spending during the late 1970s and 1980s is taken to signify this transformation.[462] This period is characterized by both negative and positive transformation pressure. Heavy, capital intensive process industries were under negative transformation pressure (i.e. increased competition and

[456] See contributions in Eliasson and Johansson (1999).

[457] Johansson 2004

[458] Johansson 1999a p. 153-5

[459] Johansson 1999b

[460] Johansson 2004

[461] Davis and Henrekson 1999; Edquist and Henrekson 2013

[462] Schön 2000 p. 512

declining demand) and industries in which firms could draw on the rapid development of microelectronics were under positive transformation pressure (i.e. windows of opportunity). The need for long planning horizons, the close demand-business cycle relationship together with the inability to rapidly adjust production to changing circumstances made capital intensive industries extra sensitive to the environmental changes from the late 1960s onwards.[463] The mining, iron and steel, pulp and paper, and shipbuilding industries were all affected by the international downturn and the profound changes in the competitive landscape. These changes included not only the increase of sheer competition but also higher energy prices.[464] Given the energy-intensive nature of process industries and other heavy industries, much of the restructuring pertained to cost cuts and the development of efficient production processes.[465] In addition, increasing specialization of products is also argued to have taken place within firms in these industries[466] Capital goods producers in the engineering industry were also sensitive to decreases in demand.[467] As much as the specialization and rationalization surge of the late 1960s and the early 1970s had benefitted such firms, falling investment ratios and the turn to immaterial investments in the crisis years were damaging to business.[468]

The positive side of the structural crisis is represented by opportunities presented by new technology. This is the *creation* element of the creative destruction process. Swedish firms entered early into the field of electronics. Production and implementation processes in the 1950s and 1960s raised the level of absorptive capacity in the Swedish manufacturing sector, and prepared the way for the penetration of microelectronics in the 1970s and 1980s.[469] High absorptive capacity, technological development, and a

[463] Schön 1990 p. 85

[464] Schön 2000 p. 488-92

[465] Schön 1990 p. 104-8, 2000 p. 490

[466] Schön 1990 p. 93, 105-8, 2000 p. 490

[467] Schön 1990 p. 90

[468] Schön 1990 p. 90, 2006a p. 69

[469] Schön 1990 p. 80-2, 2000 p. 512-3. The receiver competence is noted also by Swedish growth school scholars. Eliasson (1987b, 1990b) notes that Swedish firms were world leaders when it came to using electronics in their mechanical products.

significant decrease in production costs made for a speedy diffusion of microprocessors.[470] The cheap and small widgets revolutionized production processes, information systems, product and process development, planning, and management practices.[471] Computer aided technologies and IT-based systems penetrated the manufacturing sector in the 1980s and reconstructed activities across the entire spectrum of industries. In some industries, this reconstruction pertained to processes, whereas in others it was implemented in products. New pharmaceutical and biotechnology products benefitted from microelectronic technology, but the microelectronic revolution also implied a renaissance in "old" capital intensive industries.[472] The spread and diffusion of the new technology was transformative and challenged established wisdom and received practices.[473] The 1970s and to an even greater degree the 1980s were decades during which manufacturing firms learnt about this new technology. In the 1990s and 2000s, learning had reached a level where technology matured and large productivity gains could be realized.[474] These gains translate into economic growth.

Co-alignment of industrial structure, institutions, and policy during rationalization periods is one of the central tenets of the structural analytical perspective. When structural crisis hits, this alignment becomes an obstacle to transformation.[475] Accordingly, the match between policy in the 1970s and 1980s and the pending transformation process was prone to friction.[476] One obvious example is the tax system that favored large existing firms and restricted the potential embodied within small and startup firms.[477] Still, ill-

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[470] See Cohen and Levinthal (1990) on the concept of *absorptive capacity*; a positive spiral of knowledge.

[471] Schön 2006a p. 101-2

[472] Schön 2000 p. 445

[473] The experience that the merit of received practice is come into question is a central trait of the creative destruction process. The upheaval of widely recognized practices has far-reaching consequences for the fundamental beliefs about what technology, management style, production processes, merchandise models and distribution channel that breed success.

[474] Schön 2000 p. 509-14

[475] Schön 1982b

[476] Schön 1990 p. 94

[477] Schön 1990 p. 95

fitting policy was being gradually reformed and was not alone sufficient to block transformation. Both existing and new firms concentrated on the opportunities offered by the microelectronic revolution.[478] The 1980s experienced lively startup activity in both pure electronics and applications thereof.[479]

The 1980s is argued to have been primarily a "hardware decade" in relation to microelectronic products.[480] Firms invested massively in computers and physical infrastructure. In the mid-1990s, physical structures had reached a level of sophistication so high that investments increasingly came to regard software and complementary technology.[481] The strong growth in the second half of the 1990s and the new millennium was enabled by potential and opportunities offered by this relatively mature physical infrastructure and related human capital. The major difference between the two research traditions pertains to whether the development during the 1980s delayed or enabled this development. Whereas the Swedish growth school ascribes to the former position, the structural analytical perspective poses that the 1980s levered the strong growth of the 1990s.

3.5 Concluding remarks

This chapter opened with a short introduction to the central research debate on Swedish industrial transformation in the period 1970 to 2007. It traced the roots of recent and contemporary research and proceeded to discuss the central features of two explanatory models that were developed during the 1970s and 1980s. Some of the more influential analyses (based on these two models) of the period were reviewed under three separate headings which each correspond to one of the three research questions of the thesis. The starting point was the dominating perspective, offered by scholars writing in the so called Swedish growth school tradition. This perspective was then

[478] Schön 2000 p. 513

[479] Schön 2000 p. 513

[480] Schön 2000 p. 445-6

[481] Schön 2006a p. 146-52

contrasted with contributions from representatives of the so called structural analytical research tradition. The findings presented in the empirical chapters will be discussed in the light of the narratives summarized in this chapter. Furthermore, the concluding chapter will come back to the reviewed narratives in a synthesizing discussion of the process of Swedish industrial transformation during the studied period.

The following chapter will present and discuss the new data that is to be explored.

4. Data

The objective of this chapter is to describe the new database that is explored in this thesis and to discuss its inherent advantages and disadvantages.[482] The chapter opens with a short introduction to the database (section 4.1), after which a discussion of different types of innovation indicators follows (4.2). Subsequently, the construction and design of the database is presented (4.3). Section 4.4 scrutinizes the database through investigations and a critical discussion relating to its validity and reliability is detailed. Section 4.5 describes the variables that will be explored in the empirical chapters while section 4.6 discusses the use of complementary firm data retrieved from Statistics Sweden.

4.1 SWINNO: Swedish innovations

SWINNO: 'Swedish Innovation' is a new database constructed by Josef Taalbi and the author of this thesis. The database contains extensive information surrounding single innovations commercialized by Swedish manufacturing firms between 1970 and 2007. The new data creates unprecedented opportunities to represent technological and industrial developments in the Swedish manufacturing sector over an eventful thirty-eight year period. The database is an unparalleled source of information regarding Swedish innovation in combining both depth and width; the data contains detailed information concerning 3978 innovations. This richness in detail combined with the large number of observations makes the new data suitable to both quantitative and qualitative analyses of innovation output.

[482] Some parts of this chapter is identical with Sjöö et al. (2014).

SWINNO is modeled in the fashion of the Finnish SFINNO database.[483] As both the Finnish and Swedish databases were collected using the same object-based innovation output approach there exists considerable scope for comparative studies of innovation in the two countries.[484] Such studies could shed light on similarities and differences between two countries that typically achieve among the highest rankings on the EU's Innovation Scoreboard.[485]

4.2. Innovation indicators and measurements

Back in 1962 Simon Kuznets noted that innovation is an elusive phenomenon.[486] According to Patel and Pavitt (1997) "[t]echnological artifacts, and the organizational [sic] and economic worlds in which they are embedded, are *complex* and *everchanging*: they each comprise so many variables and interactions that it is impossible to fully model, predict and control their behavior through explicit and codified theories and guidelines".[487] The inherent difficulties in measuring innovation together with an insensitive treatment thereof in mainstream neoclassical economics spurred a group of scholars to pursue the endeavor of breaking up the "black box" of innovation.[488] The desire to understand innovation has made researchers approach the phenomenon from several different points of view. As a result, a set of science, technology, and innovation indicators are now available to innovation scholars. Depending on the indicator chosen, researchers may arrive at very different conclusions.[489] The indicators reviewed here can be characterized according to whether they are input, output, or intermediary output indicators and whether they are object or

[483] Palmberg 2003; Saarinen 2005. The Finnish data covers the period 1945 until the present.

[484] Kleinknecht and Bain 1993

[485] European Commission 2005, 2008, 2013

[486] Kuznets 1962

[487] Patel and Pavitt 1997 p. 143

[488] Rosenberg 1982; Archibugi 1988

[489] Kleinknecht et al. 2002

subject based. Input indicators measure what goes into the innovation process, like research time. Output indicators measure actual innovations, what comes out of the innovation process. Intermediary output indicators are something in between situated closer to 'invention' rather than to innovation. Object and subject based indicators both measure actual innovations, but the object based variety focus upon technical innovation per se, while the subject based type places emphasis on the innovating firm.

4.2.1 The innovation process: what goes in and what comes out

Research and development (R&D) is by far the most often used innovation indicator. The heading incorporates both the production and embodiment of new knowledge.[490] It is commonly measured as expenditure, or the share of personnel or hours worked that are devoted to R&D activities.[491] Its popularity is explained by availability, long time series, opportunities for various comparisons, and its increasing sophistication.[492] Recognizing that not all expenditure related to innovation is classified as traditional R&D (and therefore may go unnoticed) researchers have sought to estimate total innovation expenditure.[493] If innovation is defined strictly as a commercialized good, process, or service, then consequently R&D and total innovation expenditure must be classified as input indicators and/or proxies of actual innovation.[494]

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[490] OECD 2002

[491] Smith 2005

[492] The OECD time series go back to the 1960s. See the most recent Frascati Manual for a brief history (OECD 2002). Also, UNESCO was engaged in the collection of R&D data, see Sirilli (1980) and Godin (2001). It is nowadays possible to distinguish product from process R&D as well as to split data into basic research, applied research and development work (Kleinknecht et al. 2002).

[493] Brouwer and Kleinknecht 1997

[494] See OECD (1976) and Kleinknecht et al. (2002) for a critical discussion of R&D as an indicator of innovation.

Patents are another widely used indicator of innovation, classified as an intermediary output indicator.[495] The patent system aims to protect the property rights of firms and individuals to new technologies which they have been responsible for developing. The 'public good' nature of knowledge often makes technologies easy to imitate. Patents give a temporary legal proprietorship (monopoly) to a new technology. In doing so the patent system counters the tendency of underinvestment in new knowledge. The benefits of patent data include easy access and a vast number of observations. Patent data and patent citations are rich sources of information on the cumulative flow of knowledge in the economy, and the characteristics of technologies. Furthermore, the fact that applicants consider it a worthy pursuit to invest the funds and time to apply for a patent, await the decision of a patent office, and meanwhile risk the latter's disapproval indicates some perceived economic and/or technological significance.[496] While a patent is an output of a development process it primarily measures *invention* rather than a Schumpeterian *innovation* (i.e. a commercialized good, process, or service).[497] Not all patented inventions will be commercialized and all innovations of the population will not be patented.[498]

Depending on what kind of research question that is being asked, both of the above mentioned innovation indicators may be deemed appropriate: R&D feeds innovation and patents result from R&D processes. Still, a

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[495] See Griliches (1990), Archibugi (1992), and Nagaoka et al. (2010) for an overview. See Schmookler (1950, 1953) for two early accounts discussing the use of patent statistics.

[496] Kuznets 1962 p. 36. The varying value of patents has been highlighted as a point of criticism against the use of patents as an indicator of novelty and inventiveness (Kleinknecht et al. 2002; Beneito 2006). Different methods have been used to address the varying value of patents, for example composite index of patent value (Lanjouw and Schankerman 2004) or quality indices based on citations (Ejermo 2009; Ejermo and Kander 2011). See Narin and Olivastro (1988) for an approach similar to that of Ejermo and colleagues.

[497] Basberg 1987; Griliches 1990

[498] Archibugi and Pianta 1996; Arundel and Kabla 1998; Brouwer and Kleinknecht 1999a; Arora et al. 2001; Kleinknecht et al. 2002 See Granstrand (2000) for reviews of the literature. That said, there are undoubtedly patents that are important to the accumulation and development of knowledge and thus contribute to the development of subsequent innovations. See MacLeod (1988) and Sullivan (1990) for accounts of the role of patent systems to the accumulation of knowledge and the development of technology during the industrial revolution.

linear relationship, in which actual innovation can be traced by reference to R&D and patents, is difficult to isolate in practice. The same remark has been made with reference to other innovation proxies such as licenses, scientific publications, trademarks, and utility models.[499] As measurements of actual innovation, none of them are is acceptable.

Imperfections aside, R&D and patents are the most frequently used innovation indicators today. However, their prominence has been contested for several decades. In particular, the 1960s and 1970s witnessed intense debate and various measurement approaches. The discussion revolved around the benefits of input and various output approaches and engaged the OECD as well as national authorities.[500] Suggested output approaches focused on the outcome of innovation processes through the identification plus counting of, and following up on commercialized technological innovations.

The British Association for the Advancement of Science was among the first to engage in the systematic collection of innovation output data in the late 1950s.[501] The U.S. National Science Foundation and various academic institutions followed suit in the 1960s.[502] Output studies have used various methods of measurement; surveys, interviews, the opinions of experts, or the screening of trade journals, sometimes all approaches have been applied simultaneously in the same study.[503]

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[499] Mendonça et al. 2004; Beneito 2006; Nelson 2009. Another innovation indicator is total factor productivity, where the wider category of *technical change* is retrieved as part of the residual left after subractions of labor and capital. See Hall (2011).

[500] Godin 2002. See OECD (1968) for an early OECD publication relying on innovation output data.

[501] See Carter and Williams (1957, 1958) for reports.

[502] See Myers and Marquis (1969) for a report on the NSF project; see Godin (2002) for an overview of early studies.

[503] Myers and Marquis 1969; Gellman Research Associates 1976, 1982; Townsend et al. 1981; Edwards and Gordon 1984

4.2.2 Output indicators: subjects or objects

Innovation output indicators can be classified as being either subject or object based.[504] Subject-based indicators approach innovation output from the point of view of the innovating agent; a firm or a single entrepreneur responds to questions in relation to the innovation(s) for which they are responsible. Object-based indicators examine various characteristics of innovation objects themselves without referral to the innovating agent. In the history of object-based indicators, primarily two types of sources have been used; interviews with industry experts and periodicals.

Both subject and object based indicators have advantages and disadvantages. Subject-based indicators may pick up a lot of innovations and answer questions related to innovation activities in firms regardless of whether a successful outcome has been achieved or not. Object-based indicators normally capture innovations of a certain importance and do not over exaggerate innovation in the way subject-based indicators can do. Object-based methods of capturing innovation output (e.g. expert-opinion and literature searches) are argued to have been overshadowed by subject-based methods.[505] The two following sections discuss the relative merits of the two approaches relating to output measurement.

4.2.2.1 Voices of innovating subjects

Through innovation surveys, firms are asked for example to estimate their innovation output and the sales that are attributable to this output.[506] The first surveys were conducted in the 1950s and 1960s but it was not until the 1970s that surveys gained momentum as the preferred method of innovation output measurement in OECD, the U.S. National Science Foundation, and other influential organizations.[507] Since then, surveys have become the dominant source of information about innovation output.[508]

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[504] Archibugi 1988; OECD 2005

[505] Kleinknecht and Bain 1993

[506] Kleinknecht et al. 2002

[507] Godin 2002; Mairesse and Mohnen 2010

[508] Smith 2005; Sauermann and Roach 2013

The EUROSTAT-managed Community Innovation Survey (CIS) has in particular, since it was first launched in 1993, provided ample opportunities to analyze topics related to various phases of the innovation process.[509]

Surveys sent to innovating firms contain unlimited options regarding the subject to be addressed and assuming that the questions therein are fine-tuned and firm confidentiality is guaranteed, there exists strong potential to obtain useful answers. Surveys make detailed micro-level data available to researchers and enable thorough analysis of innovation processes and performance through benchmarking and monitoring.

While firsthand information regarding innovation processes and outcomes is attractive, it is not devoid of problems. The results may suffer from cognitive bias. Such bias would concern a situation where individuals, often managers with high-level responsibilities, are asked to make performance assessments. Survey answers are thus perceptual rather than objective measures. There is an extensive volume of literature on the problems related to self-reporting.[510] One major issue, widely observed in the literature, is that respondents tend to answer in such a way that is socially desirable or in a manner that makes them appear in a favorable light.[511] Asking an R&D manager to assess the output of R&D efforts is by nature an alternative method of asking this person to evaluate his or her own work. Finding themselves in an exposed position, managers may be prone to exaggerate performance, and the innovativeness of firms may thus be overestimated. An enclosed definition of innovation (or other items for that matter) is commonplace but the likelihood of over-reporting may be augmented by the fact that respondents are left with the task of assessing whether their own new products comply with the definition or not.[512] An illustration of the difficulties in retrieving valid items is provided by a real situation in which *two* completed survey

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[509] See the Oslo Manual for definitional and methodological issues related to CIS (OECD 2005).

[510] See e.g. Podsakoff and Organ (1986), Stone et al. (2000), Donaldson and Grant-Vallone (2002). See Spector (1987, 2006) for a critical discussion of any method variance bias in self-reported survey answers. For a comment on Spector´s 1987 work see Williams et al. (1989).

[511] Zerbe and Paulhus 1987; Moorman and Podsakoff 1992

[512] Landy and Farr 1980; Mairesse and Mohnen 2010

forms were sent back from *one* firm.[513] Two separate respondents had filled out the same form unknowingly, which nullified the validity of the survey. The number of innovations reported (by representatives of the same firm) in the forms differed to such an extent that the researchers found no other solution but to drop that particular question in subsequent surveys.

An additional problematic issue is that survey answers are highly sensitive to both those questions which are posed and the manner in which they are expressed.[514] Poor construct validity will have significant influence on the conclusions that can be inferred. Thus, when the share of innovation studies based on CIS increases as just one example, a problem of common method variance bias may impair our knowledge about innovation.[515] An increasing use of surveys in analyses of innovation must thus be accompanied with continuous discussions and scrutiny regarding the validity of constructs. Other factors that influence the quality of survey data include varying response rates and response biases.[516]

4.2.2.2 Messages from innovation objects

Object-based innovation output approaches were developed to shed light on the relationship between new technologies, industry dynamics, and economic development by counting individual innovations. The first-hand focus on the output objects of innovation processes has been argued to enable a measure of *innovation proper*.[517] The data retrieved may be complemented with information about the firms to which the identified innovations are assigned.

As already noted, different sources have been used to identify innovation objects. The developed approaches can be divided into two classes, those based on the opinions of industry experts and those based on the surveying of periodicals. The latter approach has been referred to as a literature-based

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[513] Kleinknecht 1993

[514] Spector 1994; Schwarz 1999

[515] Podsakoff et al. 2003, Spector 2006

[516] Sauermann and Roach 2013

[517] Godin 2002

innovation output method (henceforth LBIO).[518] The expert-opinion method is self-explanatory: industry experts are asked to list important innovations in their field and name the developing firms.[519] The bulk of LBIO studies draw primarily on industry periodicals but researchers have also relied on other historical sources. Both the expert opinion and the LBIO-method are dependent on the assessments of one or more individuals (experts, editors, or authors). An innovation that goes unnoticed by these individuals will not end up in the database. Object-based methods thus, much as with subject-based methods, rely on perceptual judgments. Still, object-based methods escape the drawbacks of self-reporting since industry experts or periodical editors are independent (i.e. they are not tied to any particular firm). The filtering of information through the perceptions and assessments of individuals (whether experts or editors) results in a "significance" bias; i.e. only innovations with a certain level of novelty are reported.[520]

Besides escaping of the drawbacks of self-reporting, object-based approaches have a number of advantages. In relying on literature sources such approaches may reveal a plethora of information concerning the innovation in question; novelty, complexity, origin, knowledge-base, development, user industries, collaborations etc., all of which are variables that can be extracted from articles in trade journals.[521] LBIO approaches enable the retrospect construction of longitudinal innovation output databases with maintained quality if it is based on literature that has been published in real-time.[522] Constructing a longitudinal database on the basis of surveys retrospectively, demands sufficiently competent individual and organizational memory. In certain firms, there may be no single individual still employed to whom questions could be addressed relating to innovations and innovation processes that took place some decades ago. Some firms may not even exist

[518] Kleinknecht and Bain 1993

[519] Townsend et al. 1981

[520] Edwards and Gordon 1984 p. 14-15; Makkonen and Van der Have 2013

[521] Some LBIO studies (e.g. Edwards and Gordon 1984; Acs and Audretsch 1990) rely on data collected from new product announcement sections. The possibility of distilling information from such limited news items is clearly restricted compared to authored articles.

[522] Coombs et al. 1996

anymore. In capturing all innovations that were at one point in time deemed significant enough to report, the LBIO method will also include innovations from firms that have not survived or those which have continued business under another trading name. The method thus presents an opportunity to assemble a dataset that has not been corroded by time or the exaggeration of reporting subjects.

Object, or count, approaches go back a long time. In 1972 Langrish et al. produced an exhaustive coverage of 84 innovations that had been given the Queens Award for technological innovation in 1966 and 1967.[523] Detailed case studies of each individual innovation were undertaken. Gellman Research Associates presented one of the first longitudinal innovation output databases in 1976.[524] 500 innovations that had been commercialized in several countries between 1953 and 1973 were identified. The innovations counted were "the most significant new industrial products and processes, in terms of their technological importance and economic and social impact".[525] The innovations in this National Science Foundation-funded (U.S.) project were identified by an international panel of experts. The Gellman Research Associates put together another output-based data set some years later (1982), this time based on the screening of fourteen U.S. trade journals published between 1970 and 1979.[526] In total, they identified 590 innovations.[527] The Science and Policy Research Unit at the University of Sussex undertook an ambitious effort when during a fifteen-year-long period researches constructed an expert-opinion-based dataset with information pertaining to 4378 U.K. innovations that were commercialized between 1945 and 1983.[528] Later, the Futures Group, commissioned by the U.S. Small Business Administration put together a dataset encompassing 8074 innovations (of which 4476 originating from manufacturing firms)

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[523] Langrish et al. 1972

[524] Gellman Research Associates 1976

[525] National Science Board 1975 p. 100

[526] Gellman Research Associates 1982. Requested by the U.S. Small Business Administration.

[527] Apart from the 590, 45 innovations from the earlier study were included (Acs and Audretsch 1990 p. 23).

[528] Townsend et al. 1981; Pavitt et al. 1987

commercialized in 1982.[529] The Futures Group screened over one hundred different trade journals in their search for innovations.

A number of object-based studies using primarily the LBIO-method were conducted during the 1990s. A volume edited by Kleinknecht and Bain collected studies on Austria, Ireland, the Netherlands, and the U.S.[530] Later, studies on the UK, Italy, Spain, and Finland have been published.[531] A recent study on "Schumpeterian swarms" of breakthrough inventions sourced data from the journal "Research & Development".[532] Since 1963 this journal has each year given a prize to the hundred most significant inventions worldwide. There are also LBIO-based studies on single industries and sectors; shipbuilding, logistics, and public service organizations.[533] The use of innovation counts to benchmark regional innovation performance has also been discussed and tested.[534] The only other LBIO database that contains long term coverage and which is continuously updated is, to the knowledge of the author, the Finnish SFINNO (Suomi Finland Innovations) database. This database contains innovations commercialized from 1945 and onwards.

4.2.2.3 Object-based studies of Swedish innovations

To date, there is only one major object-based dataset with observations of Swedish innovations. In the early 1980s Torkel Wallmark and Douglas McQueen at Chalmers University of Technology put together a dataset of the 100 most important Swedish innovations between 1945 and 1980 by screening annual reports of the Royal Swedish Academy of Engineering

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[529] Edwards and Gordon 1984; Acs and Audretsch 1990. The high number of innovations commercialized during one year only is explained by the Futures Group's choice to collect their data from new product announcements. Other studies (SWINNO included) collect data from articles authored by journal editors only.

[530] Kleinknecht and Bain 1993; Fleissner et al. 1993; Cogan 1993; Kleinknecht et al. 1993; Acs and Audretsch 1993b

[531] Coombs et al. 1996; Santarelli and Piergiovanni 1996; Palmberg 2003; Flor and Oltra 2004; Saarinen 2005

[532] Fontana et al. 2012

[533] Greve 2003; Grawe 2009; Walker et al. 2002

[534] Acs et al. 2002; Makkonen and Van der Have 2013

Sciences (IVA). The innovations identified by Wallmark and McQueen are, in the words of the authors: "the cream of the crop". The authors applied an ex post requirement of economic importance, they filtered innovations that by the year 1980 accounted for a minimum of $3.5 million of the innovating firm's turnover.[535] In 1979 the 100 innovations accounted for about 5 percent of value added in Swedish industry and 2.5 percent of GNP.[536] As a result of the criterion set for inclusion, Wallmark and McQueen's rate of innovation decreases towards the end of the period.

With regard to the level of technological significance, Wallmark and McQueen only consider patented innovations. To a large extent, the patent criterion excludes process and system innovations from being observed as such innovations are not patented as regularly as product innovation.[537] Furthermore, the Wallmark McQueen data does not consider military innovations. The dataset differs from SWINNO not only in terms of the number of observations, but also in several other aspects, not least the inclusion criterion. While the Wallmark McQueen data only represent innovations that have had a true impact, SWINNO captures every type of innovation output that was at one point in time assessed to have updated or modified the structure of the innovating firm's product portfolio to a significant extent. In addition to the Wallmark McQueen data, there is a Swedish Institute publication authored by Kjell Sedig (under the category of 'popular science') covering 59 major Swedish innovations between 1900 and 2002.[538]

[535] In 1980 year's prices. Wallmark and McQueen 1988, 1991

[536] Granstrand and Alänge 1995

[537] Granstrand and Alänge 1995

[538] Sedig 2002

4.3 Building the SWINNO database

The SWINNO database was constructed using the literature-based innovation output (LBIO) approach explained in brief above. This section describes and discusses the method applied and choices that were made in the process of collecting and constructing the data.

4.3.1 Data and capta

Working with primary sources takes both time and effort. The American economic historian Deirdre McCloskey has made the remark that the output of such work should be labeled *capta* (Latin for *things taken* or *seized*) rather than *data* (Latin for *things given*).[539] The SWINNO data was not given, but very much taken. Putting together a LBIO database is an endeavor which is particularly labor intensive. Several years were spent reading trade journals alone. In total, thirty-eight volumes (1970-2007) of fifteen different journals were screened, the number of issues exceeds 8600. The majority of journals were published monthly, with some issued on a bi-weekly and others on a weekly basis. A non-negligible share of these was read on more than one occasion. Eventually, information from over 6000 articles was recorded and categorized but the number of articles read naturally exceeds that number by far.[540]

4.3.2 Selecting journals

It has been emphasize that the adequacy and relevance of the journals are crucial for the quality of LBIO databases.[541] The identification of appropriate sources was thus of major concern. Sweden possesses not only a

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[539] McCloskey 1986

[540] Some of the innovations were mentioned in more than one journal article, over 6000 recorded articles thus resulted in the observation of 3978 innovations after the database was checked for duplicates.

[541] Kleinknecht et al. 2002

long industrial tradition but also enjoys a long tradition of periodical publications picturing technological development evolving within different industries. There are examples of both specialized and general journals. Specialized journals include 'Jern-kontorets annaler: tidskrift för svenska bergshanteringen' (*mining, iron, and steel*, founded 1817), 'Kemiska Notiser' (*chemistry*, founded 1887), 'Svensk trävaru-tidning' (*wood and timber*, founded 1885) and, 'Trävaruindustrien' (*wood*, founded 1915).[542] General technology periodicals include 'Verkstäderna' (*workshop issues* founded 1905) and 'Ny Teknik' (*new technology* in general, originally 'Teknisk Tidskrift', founded 1929).

Trade associations were contacted in order to learn and thereby obtain assistance regarding suitable journals to choose for the construction of the database. Through these contacts a relevant sample of journals could be mapped. One criterion for selection was that the journal was not associated with any particular company or was similarly biased.[543] Some of the journals had ties to trade associations while others were independent from such associations.[544] Ties to trade associations were not considered inappropriate nor to affect the reliability of a journal. Another selection criterion was that there was to be an editorial mission to report on the technological development of the industry. This criterion disqualified some of the journals that were selected in a first round. Journals focused on general technological development in Swedish industries were included to ensure broad coverage and to capture infant industries and nascent technologies that would otherwise risk going unnoticed (e.g. nano technology). The guiding

[542] The present names of the journals are (in the same order): Jernkontorets Annaler and Bergsmannen, Kemisk Tidskrift (followed by Kemivärlden), Svensk Trävaru- och Pappersmassetidning (followed by Svensk Papperstidning), and Sågverken (followed by NTT).

[543] A borderline case was Livsmedelsteknik/Livsmedel i Fokus which is owned by a foundation in turn owned by some 150 firms within the foodstuff industry. A telephone interview with a longstanding editor eased the fear that this journal had been biased (i.e. reported about innovations from the indirect owners in a positive way). Still, the editor admitted that a totally independent journal might have looked different in its content, but the comment was made with regard to critical reporting of the industry, not in relation to reports about innovations.

[544] Ny Teknik, is as one example sent weekly to all members of Sveriges Ingenjörer, a union for engineers.

principle followed was that overlap would be preferable to the existence of blind spots. The resulting data was checked for duplicates. In cases where one innovation was noted in more than one journal, the quality of the data could be improved since the information often was complementary.

The majority of the journals had been established long before the investigated period. Three journals started in the period that is being investigated: Automation (journal no. 1 in table 4.1) started in 1973, Telekom Idag (journal no. 12) in 1994, and AGI (journal no. 15) in 1972. The founding of the Automation and Telekom Idag magazines reflects recent technological and industrial developments (i.e. an increasing importance of ICT).[545] The 1970s saw a general increase in both demand for and supply of automation technologies. The same remark can be made in relation to telecommunications in the early 1990s. The same observation does not apply to the AGI, printing and publishing is an old industry, but fortunately there are only two years (1970 and 1971) that are not covered in SWINNO. Table 4.1 displays the type of industries which were the subject matter of each respective journal.

[545] Technological development in these nascent industries did not go unnoticed prior to the founding of the journals. Automation innovations were reported in both general and specialized journals prior to the founding of Automation. Likewise, telecommunications innovations were captured by for example Elektroniktidningen and its predecessors.

Table 4.1 All journals included in SWINNO, their change of names, orientation, and primary technology focus

	Journal	Orientation	Primary technology focus
1	Automation 1973-2007	General	Automation and general production process technology, e.g. robots, industrial surveillance systems and computers.
2	Ny Teknik 1970-2007	General	Electro-technology, chemistry, mining, mechanics, shipbuilding, automobile and power technology, construction of roads, houses and hydronomy, automation technology.
3	Verkstäderna 1970-2007	General	Machinery and equipment for the production of various products. Products from engineering industries.
4	Modern Elektronik 1970-1992 » Elektroniktidningen 1992-2007/Elteknik 1970-1992 » Elektroniktidningen 1992-2007	Specialized	Electronic components and equipment, telecommunication equipment.
5	Kemisk Tidskrift 1970-1992 » Kemivärlden 1992 » Kemisk Tidskrift 1992-1999 » Kemivärlden 1999-2007	Specialized	Chemical and pharmaceutical products, machinery and equipment for the production of chemicals and pharmaceuticals.
6	Livsmedelsteknik 1970-2003 » Livsmedel i Fokus 2003-2007	Specialized	Foodstuff, machinery and equipment for the production of foodstuff, packaging machines and products
7	Plastforum 1970-1977 » Plastforum Scandinavia 1977-1992 » Plastforum 1992-2000 » Plastforum Nordica 2000-2003 » Plastforum 2003-2007	Specialized	Qualities of plastics and rubber, plastic and rubber products. Machines for the production of plastics and rubber.
8	Sågverken, Trävaruindustrien 1970-1974 » Sågverken 1974-1999 » NTT Såg and NTT Trä 1999-2002 » NTT Såg & Trä 2002-2007	Specialized	Wood and wood products, wood cutting machines and similar.

9	VVS 1970-1982 » VVS & Energi 1983-1989 » Energi & Miljö 1990-2007	Specialized	Ventilation systems, equipment for the installation of pipes and ventilation systems in households and industries
10	Transport teknik 1970-1984 » Skandinavisk Transportteknik 1984-1986 » Transport Teknik Scandinavia 1986-1989 » Teknik i Transport 1989-1992 » Transport Idag 1992-2007	Specialized	Transport innovations in land, air and shipping transportation, transport and automotive equipment, automotive innovations, packaging innovations
11	Bergsmannen 1970-1977 » Jernkontorets annaler med Bergsmannen 1978-1981 » JkA: Jernkontorets annaler 1981-1987 » Bergsmannen med Jernkontorets annaler 1987-2007	Specialized	New metals, equipment and machines for mining, equipment and machines for the production of metals.
12	Telekom Idag 1994 » 2007	Specialized	Information- and communication technology, software.
13	Svensk trävaru- och pappermassetidning 1970-1990 » Svensk Papperstidning 1990-2007	Specialized	Machines and processes for the production and processing of wood, paper and pulp.
14	Textil och konfektion 1970-1983 » TEFO-Nytt: Special konfektion 1983-1986 Teko-Aktuellt från TEFO 1987-1993 » Struktur 1994-2007	Specialized	Textiles, machinery and equipment for the production of textiles and clothes
15	AGI Aktuell Grafisk Information 1972 » 2007	Specialized	Printing machines and machinery related to publishing and printing activities

The selection of journals was made to cover all major 2-digit manufacturing industries as classified by ISIC (International Standard Industrial

Classification) and the Swedish counterpart SNI (Svensk Näringsgrensindelning) (table 4.2).[546]

Table 4.2 2-digit industries and the journals covering them

SNI	Industry	Journal(s)
15t16	Food, beverages, and tobacco	6
17t18	Textiles and apparel	14
19	Leather and footware	14
20	Wood and wood products	8
21	Pulp and paper	13
22	Printing and publishing	15, 2
23	Stenkol, raffinerade petrolprod. kärnbränsle	5
24	Chemicals and chemical prod	5
25	Rubber and plastics	5,7
26	Other non-metallic minerals	11
27	Basic metals	11
28	Fabricated metal products	3
29	Machinery and equipment	All journals
30	Office machinery and equipment	1,2,3,4,15
31	Electrical machinery and apparatus	1,2,3
32	Radio, televisions, and communication equipment	1,2,3,4, 12
33	Medical, precision, and optical instruments	All journals
34	Motor vehicles, trailers, and semi-trailers	10,2
35	Other transport equipment	10,2
36	Other manufaturing	2,3,9
72	Computer and related activities	All journals
74	Other business activities	All journals

Note: For journal names see table 4.1.

It has been argued that a drawback of the LBIO-method is that small industries may not be sufficiently represented since trade journals

[546] SNI2002 is used throughout.

particularly dedicated to the development in such industries may be lacking.[547] In the case of SWINNO, such concerns are raised with regard to 'Other non-metallic minerals' which is a category without a related trade journal. Various innovations from this industry were located in generic journals. However the degree of coverage may well be disputed.[548] 'Computer and related activities' is traditionally not considered as part of the manufacturing sector, but was included to ensure sufficient reporting on innovations related to the microelectronic revolution.

4.3.3 Journal contents

The selected trade journals all generally contain the same structure. An editorial on the general state of the industry, or a specifically relevant issue typically opens the journal. Thereafter longer and shorter notes and articles follow with focus on the development of demand, competition, supply markets, technology, regulations, and other factors affecting firms in the industry. The trade journals typically end with a section concentrating on new product announcements. Received LBIO datasets differ in terms of what type of journal content they draw upon. The Futures Group database (8074 innovations) is for example based on new product announcements whereas SFINNO and SWINNO rely on articles authored by journal editors and journalists.[549] Hence, new product announcements were bypassed and authored articles were considered exclusively. This stance was adopted because it is assumed to increase the chances of capturing innovations of significant importance to the innovating firm and to the industry of which the innovating firm is a part rather than minor improvements and new product vintages with only marginal effect on the

[547] Van der Panne 2007

[548] Since the total population of innovations in the industry cannot be known, it is difficult to assess just how limited the coverage is.

[549] Edwards and Gordon 1984; Acs and Audretsch 1990; Palmberg 2003; Saarinen 2005. Collecting data from new product announcements will produce a higher number of innovations than if data is collected from authored articles.

competitive landscape.[550] The editorial mission of trade journals is to provide its readers with topical news. As goes for any actor in any industry a trade journal had better meet demand to stay relevant. To repeat, based upon this assumption, it is inferred that journals report on *significant innovations* rather than mere improvements and new product vintages. Editors are assumed to have the knowledge and experience to filter significant innovations from insignificant. Minor improvements and adjustments are thus argued to be filtered out by the methodology itself.[551] Furthermore, omitting new product announcements decreases the risk that only firms with a lot of money and forceful PR-departments are overrepresented in the database.

4.3.4 SWINNO innovations

Several selection principles were applied in the data collection process which resulted in many new products (reported by the trade journals) being dropped as observations in the SWINNO database. Subsections 4.3.4.1 through 4.3.4.3 will discuss the choices made in regard to ensure a purposive sampling.

4.3.4.1 Selection criteria

Three selection principles were applied in order to capture significant innovations exclusively. The first principle stems from the commonplace separation of innovations from mere inventions. The principle follows Schumpeter´s remark that inventions in themselves do not necessarily imply an economically relevant effect while an innovation is out in the commercial sphere.[552] There had to be a commercial interface in relation to the innovation in order for it to be included. This excluded new production process technologies that were *not* traded on the market. Regrettably, this

[550] In addition, Van der Panne (2007) observed that counting new product announcements grossly overestimated domestic innovations because sales agencies reported diligently about foreign innovations.

[551] Van der Panne 2007

[552] Schumpeter 1939

criterion limits the possibility of detecting an important aspect of technological development, in particular in those industries where process technology is more important to competitive advantage than is product innovation.[553] A growing body of literature reports the increasing importance of offering services as complements to products.[554] Where reported by the journals, service innovations were included in the database. Regrettably, the nature of such innovations (intangible with low levels of uniformity and high levels of customization) and their role as complements to products make them all too often escape the radars of trade journal editors. This comment applies also to system innovations. Yet, it is assumed that the truly significant developments in all innovation varieties are being captured. All innovations in the database are traded by a firm on a market irrespective of whether they are products, processes, services, systems or something else.

The second principle is related to the first. In order to ensure that only Schumpeterian innovations were included, this principle required that it had to be possible to trace the commercializing agent of an innovation.

The third principle relates to the significance of the innovations. The introductory chapter noted that while all innovations update the product portfolio of the innovating firm, the extent to which they do so may vary from minor to major. This aspect is difficult to measure. One way to approach it is to assess the novelty of the innovations. Thus, the third principle required explicit information detailing in which respect the innovation in question was novel, in order to make sure that incremental improvements were not included in the database.

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[553] Pavitt 1984; Laestadius 1998; von Tunzelmann and Acha 2005; Hirsch-Kreinsen 2008

[554] Davies 2004; Henkel et al. 2004; Howells 2004; Berggren et al. 2005; Fölster and Johansson Grahn 2005; Neu and Brown 2005; Kowalkowski 2006; Penttinen and Palmer 2007; Gebauer et al. 2010

Table 4.3 Inclusion criteria

Criteria	
Innovation	Following the Schumpeterian definition of innovation (see section 1.2) no mere inventions were included. Products, processes, services, and system innovations were included.
Innovating firm	The origin of the innovation had to be identified. No "orphan" innovations were included, nor were innovations from research institutes (or the like) without a commercial interface.
Novelty	An explicitly stated dimension of novelty was required.

4.3.4.2 The end of the innovation pipeline

At any given point in time a firm has a varying number of products in the pipeline. At the fuzzy front end, embryonic products are dismissed on a regular basis. Of all ideas generated within a firm a selected few will materialize and make it to the market. All innovations in SWINNO have made it through this pipeline. The data provides therefore no indication of innovation *activities*, only of the actual *output* of such activities. It is assumed that firms are less willing to submit information about early-stage projects in order not to risk imitation. The LBIO method is consequently not entirely well-suited to cover innovation activity in a broad sense. SWINNO has a success bias, if success is narrowly defined as market introduction. Furthermore, the majority of innovations in SWINNO were observed close in time to their commercialization. The innovations are thus not selected on the basis of their *eventual* impact on firm performance or industry situation, but rather on the basis of directly observed technological and/or strategic significance and novelty.

4.3.4.3 Swedish innovations

The ambition of constructing SWINNO was to assemble a data set that could be used for extensive analysis of long-term industrial transformation in Sweden, namely through the sphere of innovation. Hence, the scope was limited to innovations commercialized by Swedish firms. The scope was also restricted by the character of the empirical material. The trade journals were specifically directed towards covering the development of Swedish firms. A number of the journals contain sections with notes on foreign markets but it

has to be assumed that this treatment is not as thorough as that of the Swedish market.

The quest to identify specifically Swedish innovations required some definitions as to what represented Swedish innovation. A Swedish innovation was defined as one developed by at least one firm with headquarters in Sweden or a major development facility on Swedish soil. Another criterion for inclusion specified that the major part of the development of the innovation had to have taken place in Sweden. Few innovations were excluded because they failed to meet this criterion. If there was any suspicion that the firm named in the article was not the primary developer of the innovation, the firm's principal activities were checked in the Swedish firm register and a search for information about the firm was undertaken on the internet. The procedure allowed for an identification of a smaller number of sales agencies that were disqualified as innovators. The innovations in SWINNO are commercialized in Sweden, or in foreign markets, or both.

4.4 A critical look at SWINNO

SWINNO was constructed by way of purposive sampling. The purpose was to capture significant innovations commercialized by Swedish manufacturing firms. SWINNO is thus a subset of an unknown, if not unknowable, total population of innovations. This complicates standard statistical analysis.[555] The aim of this section is to investigate and discuss the viability, reliability, and robustness of the data.

4.4.1 Validity

One method of controlling whether SWINNO is a valid source of data on significant innovations would be to cross-check it with the Wallmark McQueen innovations and those featured in Sedig's publication from

[555] Archibugi and Pianta 1996, p. 454

2002.[556] Of the Wallmark McQueen sample, twenty-six innovations were commercialized after 1970 (up until 1980). The overlap with these twenty-six was 74 percent. The overlap with the innovations in Sedig was 86 percent.[557] According to this simple cross-check, the journals seem to capture a majority of the innovations that have been perceived as major or significant by experts.

As already noted, SWINNO includes all sorts of innovations. However, some innovations are more easily noticed and described than others. In comparison to complex process, service, and system innovations, product innovations are tangible and may hence be easier to distinguish. Services are intangible and frequently contain a low level of uniformity and a high level of customization. Furthermore, services are often supplements to products and hence risk being overshadowed by their "host product". Processes and systems usually embody a high level of complexity and may also be customized to such an extent that decreases their news value. On these grounds, it is assumed that process, service, and system innovations are less likely to be captured by trade journals than product innovations. SWINNO may hence not achieve the same status of 'valid source' with regard to data on significant process, service, and system innovations as it does when addressing significant product innovations. Still, the basic assumption applies: truly significant innovations are captured by trade journals irrespective of their variety.

While journal editors presumably possess deep knowledge about "their" industry, industry-specific innovation regimes are likely to influence the likelihood of spotting an innovation.[558] Differences in innovation regime are usually attributed to the nature of knowledge and technology and the trajectory along which they develop. A combination of both the magnitude of how radical a particular innovation is (or promises to be) and its degree of tangibility is likely to improve its chances of being detected. Slight

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[556] Wallmark and McQueen 1988, 1991; Sedig 2002

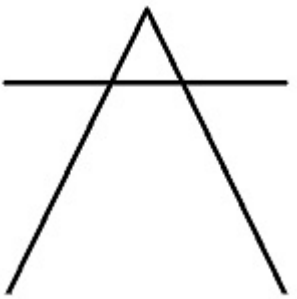
[557] Sedig 2002. Some of the innovations in the Swedish Institute publication would not have been eligible for inclusion in the SWINNO because they were either not commercialized or commercialized by a foreign firm.

[558] Dosi 1982; Malerba and Orsenigo 1997; Malerba 2005. See Castellaci (2008) for a relatively recent review of the literature.

improvements in intangible products are likely to reduce such chances. While no ambition to capture incremental innovations is intended, one problem arises with regard to intangible innovations that are by their very nature, radical. The ICT industry in particular, is saturated with such intangible innovations in comparison with most other industries. There may thus be a risk that significant ICT innovations are underrepresented in SWINNO. There is a similar risk with regard to component innovations.[559] The architecture of 'host' products may conceal component novelty. Whereas the journals upon which SWINNO are based are primarily business-to-business journals and can thus be assumed to capture innovations throughout the supply chain there is a risk that upstream innovations are underrepresented vis-à-vis downstream innovations.

Based on this discussion of validity, the coverage of SWINNO is proposed to be represented by the iceberg in figure 4.1. SWINNO captures innovations significant enough to be spotted by trade journal editors (above the surface). The lion's share of innovations goes unnoticed (below the surface). The number of innovations that are not captured cannot be assessed and hence no base of the iceberg triangle is provided. Given the limitations of the method, it is likely that some of the innovations just below the surface should have been spotted (i.e. service, system, process, and radical but intangible innovations).

Figure 4.1 Innovations in SWINNO



[559] Henderson and Clark 1990

4.4.2 Reliability

A credible test of the reliability of the SWINNO data would rely on a comparison with the results of another data gathering process following the principles described in this chapter. Preferably, the data gathering should be undertaken by researchers without prior contact with the source material. As no such test is possible we are left with the remaining option of comparing the SWINNO data with other types of innovation data. Such comparisons serve several purposes relating to the possibility that SWINNO is biased with respect both to innovations from firms of a certain size or to innovations originating within certain industries. With regard to potential firm-size bias, one could find reasonable arguments to expect both large and small firm bias. A large firm bias could be expected because such firms are by their sheer size, important to an industry and their activities are hence likely to be closely followed by trade journals. Furthermore, large firms possess the resources to sustain a media interface. A small-firm bias could be expected because large firms are preoccupied with international contacts rather than maintaining relations with domestic trade journals. A small firm may in contrast, actively seek contact with such journals. Being featured is likely to have positive ramifications for business. However, no signs of firm-size bias were found when the Finnish and Dutch LBIO databases were compared with the CIS data of each country respectively.[560] With regard to potential industry bias, it was found that journals miss out on certain industries (e.g. natural resources, food and beverages, and primary metals).[561]

The SWINNO data was compared with the Swedish CIS data for the benchmark periods 1998-2000, 2002-2004, and 2004-2006.[562] The comparison regards the number of innovations and the relative frequency of innovating firms in employment classes and sectors. The comparison is restricted to firms engaging in product innovation. The comparison of the

[560] Palmberg et al. 2000; Van der Panne 2007. Signs of small firm bias have been found in data based on new product announcements (Coombs et al. 1996, p. 405; Santarelli and Piergiovanni 1996). Edward and Gordon (1984) argued the opposite; that large firms may be overrepresented.

[561] Van der Panne 2007. Of these, only food plus beverages and primary metals are part of the manufacturing sector.

[562] The approach follows that of Van der Panne (2007).

size of the innovating firms regards only the 1998-2000 benchmarks as later CIS reports present only crude employment categories. It was found that in these years, CIS reports a total number of innovations that is about twenty times higher than that in SWINNO for the same years. It is clear that CIS and SWINNO capture innovations of different sorts.

Two cautionary remarks shall be made. First, the CIS data does not capture firms in the employment category 0-9 employees, while SWINNO captures firms of all sizes. Second, due to the sampling procedure, CIS might somewhat exaggerate the number and share of large firms.[563] The comparison shows that the relative share of small firms in SWINNO is *smaller* than that in CIS.[564] Hence, despite a possible exaggeration of the share of large firms in CIS and conversely, the representation of the very smallest firms in SWINNO, the latter displays a larger share of large firm innovations than CIS.[565] With regard to the comparison of the distribution of innovating firms across different industries, there was a high degree of correlation between SWINNO and the CIS data for all three benchmark periods.[566] There are however some slight differences; SWINNO captures relatively fewer firms innovating in the food and beverages industry, and relatively more firms innovating in the 2-digit industries 30-33.[567] Whereas there are considerable differences in the sampling methods of SWINNO and CIS, this comparison has given an indication that SWINNO is relatively reliable and unbiased when it comes to the distribution of innovating firms across employment classes and industries.

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[563] In the employment classes 10-249 employees, the firm population is sampled (between 20-35% of the population), but in the employment classes 250+ , the entire population is selected for surveys. This is likely to produce an exaggeration of the relative number of innovating firms in the employment classes 250-499 and over 500. The response rates across employment classes are however similar (ranging from 43% to 51%).

[564] See Sjöö et al. (2014).

[565] The discrepancy between the data sets may arise from some crucial methodological differences. CIS may pick up innovations which, are new to the firm, but not new to the market, while the SWINNO data captures fewer innovations that are "only" new to the innovating firm.

[566] The primary sector of the activity of the firm was compared.

[567] 'Office machinery and computers' (30), 'Electrical machinery and apparatus, (31), 'Radio, television, and communication apparatus and equipment' (32), and 'Instruments' (33).

4.4.3 Robustness

A critical issue concerns the robustness of the SWINNO data spread over time. There is a risk that both changes and bias in publication policies of trade journals and differences in the publication policies across trade journals may influence the data. This risk was assessed through semi-structured interviews with current and former editors of the individual trade journal on which the data is based and an additional test of the dependence of the results upon the inclusion or exclusion of particular journals.

4.4.3.1 Editor interviews

It was noted in section 4.2.2.2 that object-based methodologies such as the LBIO method do not escape the risk of a selection bias due to the particular perceptions of those that report them. In order to better understand trade journal reporting, former and/or present day editors of all journals were interviewed about selection processes and publication policies. In sum, 17 semi-structured telephone interviews were conducted. The first question determined the sources scanned for information about innovations. The interviewees all responded that a variety of sources normally inspired the writing of an article regarding a specific innovation. None of the editors stated that their main source of inspiration were press releases. Although press releases were screened on a regular basis, the importance of other sources of information was generally given greater emphasis. Extensive personal networks, industry experts and analysts, researchers, editorial boards (consisting of all before mentioned categories), research funding agencies, other journals, presence at industry fairs, conferences, and information acquired through a general active outreach, could all contribute to the decision to write an article on a particular innovation project. The message consistently obtained from the interviews was that journal editors use not only their own industry knowledge, but the knowledge possessed by a range of other sources, independent as well as subjective. Two journals deviated from this picture. 'Struktur' (textiles and apparel, journal no. 14 in table 4.1) was first published jointly by different employers' associations and later by the research institute IFP (Institutet för fiber och polymerteknik) and the industry research institute (Svenska textilforskningsinstitutet). Following the takeover, the content of the journal was influenced by the research institutes with the result that research results rather than products were reported on. Nonetheless, it was claimed in the interview with a former

editor that the journal had a broad scope and included any relevant development in the industry, the lack of reports regarding innovations were argued simply to reflect the infrequency of innovations within the given industry. The second exception is 'Bergsmannen med Jernkontorets Annaler' (iron and steel, journal no. 11 in table 4.1). A large part of the content of this journal is strongly influenced by the trade association Jernkontoret and the mining engineer society Bergsmannaföreningen. The relationship between the journal and these two associations is long and close and isolates the journal from the others in terms of editorial freedom. Nevertheless, the interviewee reports on a general mission to cover any important development in matters of mineral and metal extraction, refinement, and production.

A second question concerned whether the journals reported more actively about innovations originating from large firms than those coming from small firms, or vice versa. None of the editors reported a deliberate ambition to report innovations from firms of a particular size. The ambition was rather to cover innovations from all types of firms. This aside, some editors reported that they tended to feature more innovations from large firms than from small firms. This was reported by the editor of Svensk trävaru- och pappersmassetidning (pulp and paper, journal no. 13 in table 4.1). However, those editors implied that this tendency was only reflected the locus of innovative activity in "their" respective industries. Editors were content that on average they captured the important innovations, irrespective of origin but admitted that missing out on an important innovation from a small firm is more likely to occur than if it is produced by a large firm since the latter category is more constantly monitored.

A third question related to the possibilty of any major changes having taken place during our period of study through the use of different sources, the tendency to report about innovation, and the overall editorial mission of the journal. Naturally, former editors could share more information about historical changes of content and content selection processes than could current ones. None of the editors reported any major changes in the two above respects but in terms of sources, several admitted that the advent of the internet had made scanning a wide range of sources much less time consuming and far more efficient. There is thus the possibility that access to a wider array of sources results in increased coverage which would lead to growth in both the total quantity of innovations and the variety of innovations that are reported; i.e. those innovations that for some reason

were not likely to have been picked up when sources of information were more limited. Nonetheless, although editors have updated their way of conducting research, the same evaluation process applies and there still exist limitations in terms of physical journal space. One can assume that the flood of internet-bound information has equipped editors with greater possibilities of increasing the amount of shorter notes, but given limited space and author resources we conclude that it is not likely that the number of innovations featured in journal articles is influenced to any greater extent by the advent of the internet. While the greater load of information is likely to have influenced the presence of trade journals on the internet, it is less likely to have changed the content of the physical journals with regard to the craft of journalism. Any suspicion that various other sources of information would have decreased the relevance of trade journals was rejected by the interviewees; in the face of competition, trade journals have indeed been forced to work ever more diligently to stay relevant. Despite their longstanding presence and reputation they have to work hard to remain credible to their audience as sources of important industry information.

A small minority of the editors reported about changes in the contents of their respective journals. Such reports specified the introduction of special pages devoted to research results from research institutes. This was not considered a problem since those special pages rarely reported on innovations but instead focused on research results. Other editors, for example those of Livsmedelsteknik (6) and Textil och Konfektion (14), reported that the number of innovations featured in the journals has increased over the years. However, this increase was argued to have been justified by genuinely increasing innovation activity.

The interviews conveyed the picture that the content of the journals are balanced with regard to firms of different sizes and sources. Furthermore, the impression was that editorial missions and publication policies have been relatively consistent over time. Content changes were reported to reflect corresponding changes in the covered industries. Based on the interviews we contend that the innovations reported in the trade journals are carefully evaluated in terms of newsworthiness; they are singled out from a large number and a wide variety of innovations. The innovations featured in the articles are assessed as being special in some sense. The innovations on which SWINNO is based therefore do not represent innovation activity in general, but rather present a collection of innovations of such significance that they have been considered sufficiently interesting to warrant report in journals.

These journals by their very nature aim to provide their readers with reports of relevant and noteworthy developments in a particular industry. As such, we are quite certain that the innovations observed in the database capture the *locus of significant innovation* in a given industry.

While journals and editors are largely independent reporters regarding innovation, they are still human. It is plausible that they do not always manage to fulfill their professional ambitions. This may be due to resource constraints (financial, cognitive, time etc.). Such constraints are likely to influence the extent to which the editorial mission is met. Although the interviewed editors were generally modest about the fact that editorial missions may not be met one hundred percent all of the time, they were confident that they more or less captured the lion's share of significant innovations within their subject area. Such statements however suffer from the same problems that any self-reporting does; editors may over-estimate the extent to which they manage to identify all important developments with their respective radar scopes.

4.4.3.2 Journal sensitivity

Although the interviewed editors did not report any major changes in publication policies or selection principles there still exists a risk that changes therein have an effect on the counting of innovations as well as their distribution across firms of different sizes or of different industries.[568] Furthermore, it is possible that the data is heavily influenced by one or more trade journals and hence, changes in the publication policies of these journals would potentially skew the data. One method of approaching the question of robustness could be an investigation of whether the data is sensitive to the inclusion or exclusion of certain journals. For instance, one could assess whether the count of innovations over time is heavily influenced by the number of innovations found in a certain journal or whether it is general in character. If the results do not depend on the inclusion or exclusion of certain trade journals, it is possible to say that the results are insensitive to *hypothetical* changes in publishing policies of particular journals. The innovation distribution over time and across industries is then above suspicion of liability to publication policies of trade journals.

[568] Kleinknecht et al. (2002) raise this issue.

Sjöö et al. (2014) undertake a formal analysis attempting to discern what transpires in the temporal, firm-size, and industry distribution when specific journals were included or excluded. The analysis demonstrates that the shape of the innovation count curve is relatively robust.[569] The pattern is due to two general and robust tendencies: machinery and equipment innovations display an increase during the 1970s and 1980s and a sharp fall thereafter, and ICT innovations display an increase following 1990. The trend of innovations in these two industrial fields is not dependent upon one or a few specific journals.[570] Fabricated metal, rubber, and plastic innovations were also found to be insensitive to the inclusion or exclusion of journals. These are all important product groups in total innovation output.[571] Trends in other product groups were sensitive. Results were according to expectations, in particular with regard to machinery and equipment and ICT innovations as those are widely applied and used. In this regard, the sensitivity of the instrument innovation trend was not expected, as instruments are also used throughout the manufacturing sector and would thus be expected to be reported in a large number of journals. The size of the innovating firms was robust with regard to total innovation output.[572] When broken into product groups it was found that the size of the innovating firms in foodstuff, rubber, plastics, and machinery and equipment was sensitive to the inclusion of specific journals. In relation to foodstuffs, rubber, and plastics such a result was largely expected as there are specialized journals covering these industries. The sensitivity of innovating firm size to the inclusion of certain journals may be attributed to the possibility that the size of firms producing e.g. machinery and equipment for different industries may differ. Excluding a specialized journal may hence take away some of the variation in firm size.

[569] Sjöö et al. 2014

[570] See appendix B.

[571] See appendix B.

[572] Sjöö et al. 2014

4.5 Variables

The SWINNO database contains a range of variables that enable a comprehensive analysis of innovations and innovating firms. The following subsections will describe the variables used in the thesis.[573]

4.5.1 Innovations

SWINNO contains information about 3978 innovations. Descriptions of each and every innovation are included in the database. These descriptions are based on the information presented by the journal articles. If not otherwise stated, the year of commercialization of the innovation is taken to be the same as the article publication year.

4.5.2 The innovating firms

The innovating firm is responsible as the primary developer of the innovation for which it appears in the trade journal article.[574] This applies to 97 percent of the cases. With regard to the remaining three percent of the cases, the 'innovating' firm only took minor part in the development of the innovation. In these cases the primary developer of the innovation was either a non-commercial agent such as a university or a research institute or a firm who had licensed the particular innovation out to the commercializing firm.

4.5.3 Industry codes

All innovations in SWINNO have five-digit codes that correspond to Swedish national standard classifications of economic activity. This industrial nomenclature (SNI, *Svensk Näringslivsindelning*) is similar to the

[573] For a thorough account of all variables in the data set, consult Sjöö et al. (2014).

[574] Either as a manufactured product or a license.

international standard nomenclatures NACE and ISIC.[575] During the period studied in this thesis, SNI was revised two times; in 1994 and 2003. SNI69 was replaced by SNI92 in the 1994 revision whereas SNI92 was replaced by SNI2002 in the 2003 revision. The greatest changes occurred in the first revision. The purpose of the change was to more accurately reflect technological development. To be able to compare innovations across the period, all innovations were coded according to SNI2002. It was assumed that coding older innovations by a latter day classification system would be easier than the reverse scenario. Nonetheless, the nature and volume of technological change that has taken place during the period poses some coding difficulties. An example of this can be seen in the embodiment of software in industrial process control equipment in the 1970s and 1980s. Later on, software became a mass product with immense variety and application potential in its own right. The principle that was followed was that the code should reflect the primary function of the innovation.

4.5.4 Novelty

Two different variables regard the novelty of the innovations in SWINNO. The market novelty variable reveals whether the innovation is new to the world market or not, and the firm novelty variable displays novelty from the perspective of the individual firm. The firm novelty variable should be regarded as a complement to the market novelty variable. Though an innovation may not be new to the world market, it may be truly novel to a firm.

4.5.4.1 Market novelty

The assessment of the market novelty variable requires knowledge of each and every industry included in the database. Given the limited knowledge of the constructors of the database, we were compelled to rely upon information in the trade journal articles. This led to a binary variable

[575] An alternative nomenclature is SPIN (Svensk Produktindelning för Näringslivet); a product classification system. SPIN 2002 is entirely based upon SNI 2002 but is more fine-grained than SNI; it has a seven digit level while SNI stops at five. However, the further subdivision of SPIN was not considered crucial. See SCB (2003).

structure. Either the article stated that the innovation was new to the world market, or it did not. To the extent that the articles omitted such information, the number of new-to-the-world innovations is underrepresented in SWINNO. 22 percent of all innovations in the database were new to the world market. 97 percent of all new-to-the-world innovations were matched to firm size data. The number and share of the total number of innovations in the database is discussed in chapter five. Chapter six explores the variable in a firm-size perspective.

4.5.4.2 Firm novelty

The firm novelty variable is categorical and can take on three different values. The dichotomous classifications found in the literature proved insufficient to account for the different degrees of firm novelty found in the empirical material. The variable was constructed by evaluating the information provided in the trade journal articles, and for that a considerable amount of internet research on the firms was necessary. *High* firm novelty captures innovations that represent a virtual leap, either technologically or strategically. A technological leap will be considered an innovation which is responsible for breaking new technological ground. This could include for instance a new drug with unique properties, such as for example Astra's Losec. A strategic leap on the other hand, implies diversification or the firm entering a non-traditional specific niche. Examples of historical strategic leaps include the launch of an oil boom by Gullfiber (a manufacturer of insulation products) and the offshore industry shift in focus adopted by Götaverken in the late 1970s. A highly novel innovation constitutes a major modification of the structure of the product portfolio of the innovating firm. *Medium* novel innovations are those found at some distance from current technology and strategy, but that do not qualify as highly novel innovations. Innovations of *low* firm novelty are those that do not break with current technological or strategic trajectories to any great extent.

96% of all innovations in SWINNO were given a firm novelty code. The novelty of the four remaining percent could not be assessed and were hence

not coded.[576] 41 percent of the innovations were coded highly novel, 44 percent were categorized medium novel, and 15 percent of all innovations were classified as being of low novelty. The dominance of high and medium novelty innovations indicates that SWINNO primarily captures truly novel innovations, which is to be expected. Low novelty innovations are individually less spectacular and thus less likely to catch the attention of trade journal editors. One important qualification here is that low novelty innovations may also turn out to be important as the firm novelty variable is an assessment of *novelty* not *impact*. Startup firm innovations where considered highly novel by nature since such firms do not have a track record against which new innovations can be compared.

4.5.5 Startup-firm innovations

Some ten percent of the innovations in SWINNO were commercialized by startup firms. Startup-firm innovation was defined as an innovation put on the market by a firm whose founding was motivated by the launch of the innovation in question. The variable relies exclusively on explicit statements in the trade journal articles.

4.5.6 Academic spin-off innovations

Five percent of the innovations in SWINNO were the result of a commercialization of research results in an academic organization (institute or university). Academic spin-off innovations include those innovations commercialized by startup firms (i.e. academic spin-off firms) and innovations developed in universities and research institutes but commercialized by existing firms. Similar to the startup-firm innovation variable, the academic spin-off innovation variable relies upon explicit statements made in the trade journal articles exclusively.

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[576] The following share of innovations was not assessed for each presented period interval- 1970-1979 five percent, 1980-1989 three percent, 1990-1999 six percent, 2000-2007 three percent. The missing observations were distributed evenly across the firm size spectrum with an average of four percent of each size-class' innovations missing the firm novelty variable.

4.6 Firm data

Data on the innovating firms was obtained from Statistics Sweden. 97 percent of the observed innovations could be linked to a firm that in turn could be matched with a firm identification number ("organisationsnummer").The remaining three percent were distributed relatively evenly over the period.[577] The firm identification number signifies an organizational entity. All firms headquartered or otherwise primarily based in Sweden are required to possess a firm identification number. Since the relevant bill was passed in 1974 and implemented in 1975, firms were allocated organization numbers retroactively.[578] A firm register (CFAR, Centrala Företags och Arbetsställeregistret) was initiated in 1968 but has only been digitized from 1972 onwards. Firms that innovated in 1970 and 1971 were, to the extent that they could be observed in 1972, assigned that year's (1972) identification number and data for that year was likewise used. Having to use 1972 data for the years 1970 and 1971 is unfortunate and probably implies that we have not detected potentially important changes that occurred between those years and 1972. The magnitude of such changes cannot be assessed and therefore necessarily biases the SWINNO dataset. There is also the risk that the firms that innovated in 1970 and 1971 were inactive by 1972 and would thus be missed entirely. However, a quick glance at the missing Statistics Sweden data suggests that this is merely a minor problem; only seven percent of the innovations commercialized in 1970 and two percent of those commercialized in 1971 could not be matched with firm size data.[579]

4.6.1 Multidivisional firms, mergers, and acquisitions

The data obtained from Statistics Sweden is inconsistent with regard to whether the information pertains to subsidiaries or corporate groups. This

[577] 96 percent in the 1970s, 96 percent in the 1980s, 96 percent in the 1990s and 98 percent in the 2000s.

[578] Skatteverket 2011

[579] To be compared with three percent of the innovations in the entire database.

inconsistency is explained by the varying detail with which firm information is provided by the trade journals, together with the difficulties afflicting the matching of firm names (as given by the journals) with firm identification numbers (a procedure outsourced to Statistics Sweden). Multidivisional structure is primarily a characteristic of large diversified firms and consequently inconsistency is a problem related chiefly to the handling of these companies, rather than concerning small unitary firms.[580] Such large firms play an important role in SWINNO as well as in the Swedish economy and a consistent treatment of them is therefore of paramount importance.[581] The journals continuously reported on innovations from subsidiaries as well as parent firms. In the case of the most persistently innovating parent firm- identified as ASEA/ABB- no less than 48 assorted identification codes could be matched to the various firm names given by the journals.[582] In repeated cases, it was obvious that the information that followed the identification codes was outdated. For example, ABB Instrumentation was matched with the identification code for ABB Automation Instrumentation AB; a firm with zero employees. Clearly, the name provided in the article did not reflect the current organizational structure. Such structures are fluid and identification codes are thus somewhat intermittent.

Any principle concerning treatment of corporate groups must be related to the level of analysis, which in turn depends upon the research question. If the questions that are asked relate to manufacturing process operations, then the subsidiary or the business unit may be deemed an appropriate level of analysis. If the question that is posed is directed towards a Schumpeterian framework, then the corporate group would be more appropriate. Given research question two (*Did firms of all sizes innovate to the same extent during the period?*) the choice was made to concentrate on the corporate group level. There are several motivations of this choice. The first relates to the number

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[580] Chandler 1962; Rumelt 1974; Fligstein 1985

[581] Jagrén 1993; Andersson et al. 2012

[582] Percy Barnevik, the former CEO of ASEA/ABB, launched a 'divisionalization' program in the 1980s. The wave was not unique to ASEA/ABB but was a general management trend during the 1980s (Eliasson 1988b; Olve and Ekström 1990). In 1983 Asea/ABB had 73 subsidiaries (Örtengren 1985). Later, such developments were reversed through consolidation and divestiture across the economic spectrum.

of innovating firms. Using the subsidiary as the level of analysis, there is a risk that fluctuation in the number of innovating firms reflects managerial fashions only and not genuine changes. Any single innovating firm in one chosen year may in any other year become three if the corporate group for instance chooses to divide organizational operations into stand-alone business units. Another motivation, relating to the distinction between Schumpeter Mark I (innovations are mainly developed by entering entrepreneurs) and Mark II (innovations are mainly developed by large enterprises), is that if the subsidiary level should be chosen, there remains a significant risk that a new division would be confused with new firm entry and thus Mark II would be confused with Mark I. Several researchers have argued that an analysis of corporate groups paints a more appropriate picture of changes in firm populations.[583] The third motivation is that although subsidiaries or business units are (varyingly) autonomous, they report to the corporate group and major reconfigurations are likely to require sanctioning from the corporate management, both in terms of strategy, finance, and other resources.[584] In addition, subsidiaries are likely to have access to the corporate group's pool of assets and resources. Expertise and skills related to for example purchasing, product, process, and packaging design, marketing, and distribution may flow between subsidiaries of a corporate group.[585] Treating subsidiaries of groups as individual firms would neglect the advantages of having access to such flows and pools of resources. A related motivation regards the number of employees. While the number of employees is a common measure of firm size it may change in accordance with structural reorganization. ABB Automation Instrumentation AB is a case in point; the subsidiary had been emptied of employees which, one might reasonably assume, were now active elsewhere within the firm.[586]

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[583] Davidsson et al. 1994; 1996; Henrekson 1996; Henrekson and Johansson 1997; Johansson 1997; Henrekson and Stenkula 2006; Bjuggren and Johansson 2009; Henrekson et al. 2012

[584] Gupta 1987. The pooling of resources has inspired network analyses of multidivisional firms in which transaction between members of corporate groups have been studied. See e.g. Gupta and Govindarajan (1991, 2000) and Almeida et al. (2002).

[585] Gupta and Govindarajan 1991, 2000; Hansen and Lovas 2004; Monteiro et al. 2008

[586] There is of course also the possibility of a divestment.

The "divisionalization" surge was not the only management trend that changed the structure of firms. From the 1960s onwards, mergers and acquisitions became increasingly more frequent.[587] Not least, the nationalization of crisis-ridden firms contributed to changes in firm population. Accounting for all of these changes in the database was not possible, not least because small firms also go through the process of merging and acquisition. It was judged sufficient to scrutinize the firm histories of the more frequent innovators, who, with few exceptions, were also multidivisional firms. As the choice was made to analyze the firms primarily at the level of the corporate group, it was necessary to construct groupings that reflected organizational changes in a coherent way, in order to be able to assess the total amount of innovation output of a particular group. One central focus that had to be considered throughout was to account for the year in which two formerly independent firms joined forces in a corporate group, and alternatively when (if it was the case)such groupings were dismantled. A table describing the principle followed with regard to individual firms can be found in appendix B. The table reports only the most complex cases.

4.6.2 Firm size

Unfortunately, there is no single standard or template when attempting the division of firms of different sizes into classes. The European Union defines large firms as those with more than 250 employees, medium-sized firms as those with more than 50 employees, small firms as those with more than 10 employees, and micro firms as those with less than 10 employees.[588] The U.S. Small Business Administration definition of small firms differs depending on the particular industry the firm is active in.[589] Hence, a small firm can have up to 1500 employees if it is active in for example the petroleum refining industry. Some contributions apply a 500 employee cut

[587] Bergholm and Jagrén 1985; Jagrén 1988

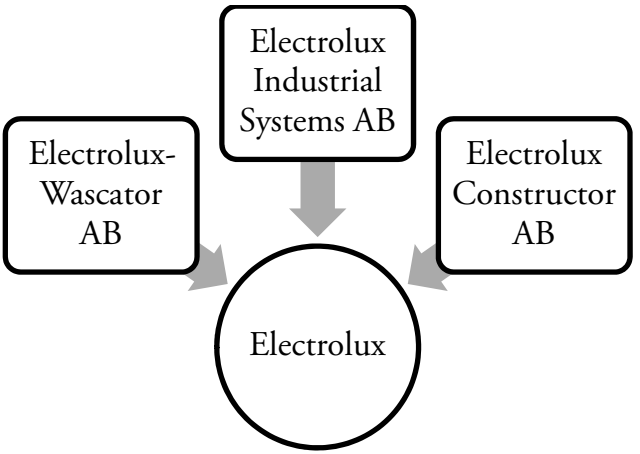
[588] European Commission 2003

[589] Small Business Administration 2013

off to define large firms.[590] The majority of accounts of the development of Swedish firm population use more fine-grained categories.[591] This thesis defines small firms as those with less than 50 employees, medium-sized firms as those with between 50 and 499 employees, and large firms as those which contain in excess of 500 employees.

Exposure to the whims of corporate management and vertical/horizontal resource ties are both typical features of multi divisional firms. This motivated the key decision to choose the corporate group as the level of analysis of multidivisional firms. This extends to the number of employees also. Cases where subsidiaries are reclassified from one size class to another are distinctively rare, since such firms would rarely employ less than 500 employees. The practical principle followed was that all subsidiaries were assembled under the smallest possible denominator as in the example of Electrolux (figure 4.2).

Figure 4.2 Electrolux and subsidiaries



[590] Acs and Audretsch 1988; Braunerhjelm 1993

[591] E.g. Johansson (1997), Henrekson and Stenkula (2006), Henrekson et al. (2012)

5. The temporal pattern of innovation

The objective of this chapter is to explore and discuss the temporal pattern of innovation against the backdrop of the development of the aggregate economy and specific aspects of change in the manufacturing sector. The empirical investigations will address changes in both the number and novelty of the innovations in order to answer research question number one: *Was there a key period of innovation and if so, when did it occur?* In the first part, the number of innovations will be explored as a single subject, in relation to the development of the aggregate economy, and in relation to variables describing the development of the manufacturing sector. In the second part, investigations will differentiate between more and less novel innovations. The differentiation aims to elucidate whether any sub period exhibits a larger share of highly novel innovations and hence more profound measures of transformation. In the closing section, the findings of the chapter are discussed in relation to the received analyses of structural transformation during this period.

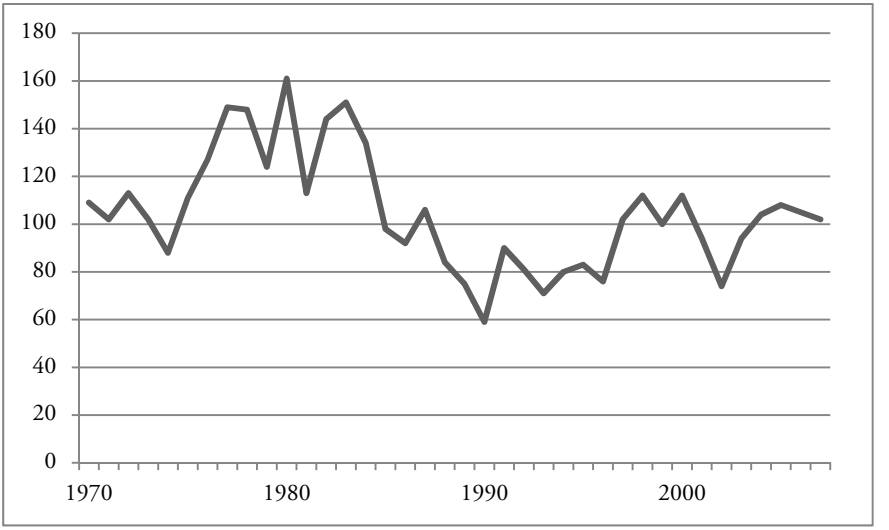
5.1 The basic innovation pattern

The issue of whether innovations are launched continuously or discontinuously was a central question of the literature review in chapter one. The review conveyed that irrespective of whether the macro, industry, or micro level is considered; there are theories and empirical accounts suggesting the existence of both continuous and discontinuous innovation. There are those that argue that innovations appear as a constant drizzle and there are those that argue that this drizzle is, occasionally, interrupted by periods of downpour that floods and changes the technological and industrial landscape. The former supposition characterizes early formulations of growth models with endogenous technological changes

whereas the latter supposition is characteristic of evolutionary theories of economic growth and long waves as well as economic historical narratives. Among theories and accounts that assume discontinuous innovation, there runs a dividing line between those that suggest significant innovation to be a downturn phenomenon and those that suggest it to be primarily an upturn phenomenon.

The innovation count data (figure 5.1) suggests with respect to the time span studied in this thesis, that the incidence of innovation is discontinuous rather than continuous. The data on the number of innovations shows the period between the mid1970s and the mid1980s to be the most innovation intense. Even though the number recovers (save for a marked drop at the time of the dot.com crisis in the early 2000s) after falling to a trough in 1990 it does not reach the same level as that reached in the preceding decades.

Figure 5.1 Innovations, 1970-2007 (n=3978)



The overarching research question posed in the introductory chapter of this thesis concerned the association between structural transformation as represented by changes in the quantity and character of innovation output and long term fluctuations in the Swedish economic growth rate. Table 2.1 showed that Sweden lagged behind several comparable countries in the period 1975 to 1995. Thereafter, the Swedish economy recovered and grew

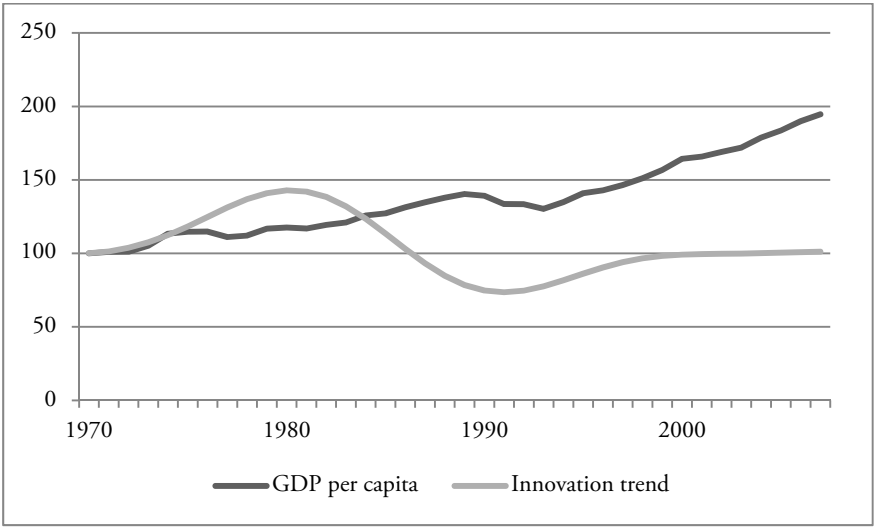
relatively strongly until the end of the period. Chapter two described Swedish economic and industrial development in some detail. Sections 5.2 through 5.5 discuss innovation output against the backdrop of this development.

5.2 Long-term fluctuations in innovation and GDP per capita

While the long-term trend of the innovation data comes out clear in figure 5.1, it is possible to make it even more clear by detrending the series (i.e. filtering away shorter cycles).[592] Figure 5.2 shows the remaining long term innovation trend plotted against the development of GDP per capita. The figure reveals that the period when innovation output was unambiguously at its greatest (approximately 1975-1984) occurs at the same time as GDP per capita grows particularly slowly. While the innovation trend increases during the financial crisis in the early 1990s, it levels off in the new millennium.

[592] Filtering techniques separate different time horizons in the data by decomposing it into a trend component and a cycle component. The trend component is the long-term development of the series, undisturbed by short-term fluctuations. The cycle component is the short-term development of the data. Here, the filtering is done by help of wavelet transformation, a kind of frequency domain analysis. See Andersson (2008) for an introduction to wavelets and further references.

Figure 5.2 Innovation trend (n) and GDP per capita (constant prices) 1970=100, 1970-2007



Note: The wavelet transformation was performed by Fredrik N G Andersson. Source: GDP per capita: Schön and Krantz 2012.

An immediate reading of figure 5.2 could posit that the innovation performance of the Swedish economy was strikingly strong in the extended period of slowdown, stagnation, and decline in the late 1970s and early 1980s, but notably poor in the period of strong growth after the 1990s crisis. One could thus infer that innovation is counter cyclical vis-à-vis GDP per capita growth. However, the manufacturing sector is not the only constituent of GDP. To assess whether innovation output is counter cyclical vis-à-vis growth it is necessary to take changes in the structure of the economy into account. One could argue that the innovation output is perhaps not that meager given the decreasing relative importance of the manufacturing sector discussed in the introductory chapter. To the extent that the strong growth in GDP after the 1990s crisis is associated with the expansion of the service sector, expecting the innovation output of the manufacturing sector to grow on par with GDP may prove excessively optimistic. However, given the increasingly close interaction between the service and manufacturing sectors a strict distinction between them has been

argued to be irrelevant.[593] Many service firms are highly dependent upon manufacturing firms as customers and as such the latter sector is indirectly responsible for a large share of employment and income. In addition, with regard to contribution to real GDP, it has been shown that the importance of the manufacturing sector in the Swedish economy is not actually reduced in this period.[594]. Explaining the seemingly poor innovation performance in the period after the 1990s crisis with references to a downplayed role of manufacturing in terms of both direct and indirect contributions to employment, income, and GDP (real and nominal) seems thus to be problematic. The diverging innovation and economic growth trends need to be further explored.

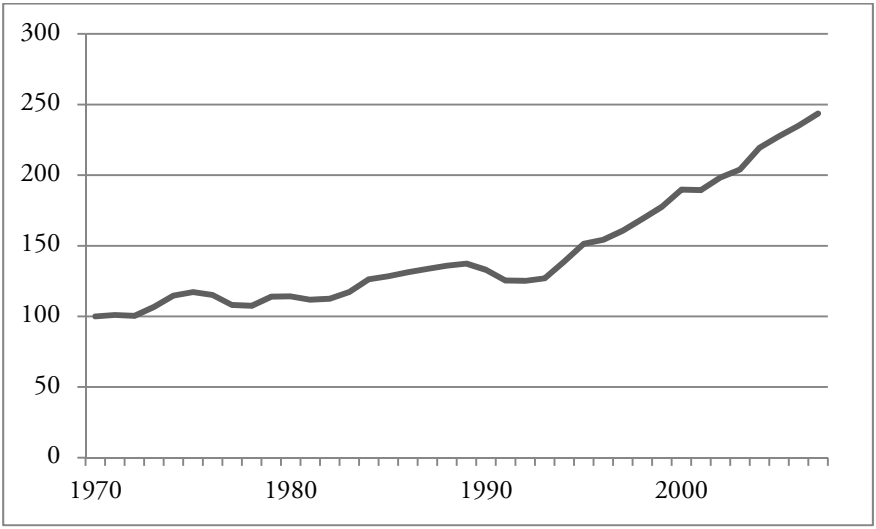
5.3 Innovation, value added, and productivity

The growth of real value added in the manufacturing sector during the period is shown in figure 5.3. The pattern is more or less the same as that of GDP per capita, albeit the positive trend in value added after the 1990s crisis is more pronounced than that in GDP.

[593] Chapter one, section 1.3.3.

[594] Kander 2005; Henriques and Kander 2010. A discrepancy between the service sector's nominal and real contribution to GDP is referred to as an incidence of Baumol's cost disease; to cope with wage increases enabled by increased productivity in the manufacturing sector, firms in the service sector have, in the absence of the same possibilities of productivity increase, been forced to raise prices.

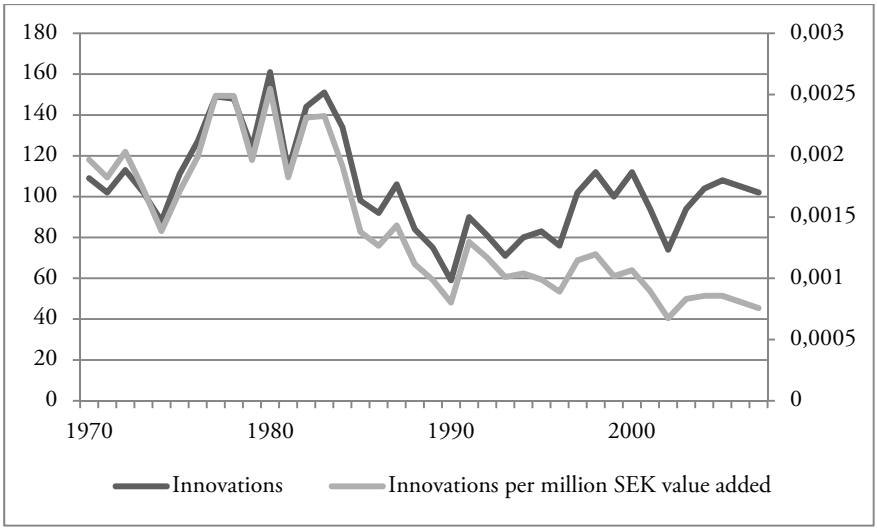
Figure 5.3 Value added in the manufacturing sector, 1970-2007 (constant prices, 1970=100)



Source: Schön and Krantz 2012.

Innovation; a new combination whose value exceeds the sum of that of its constituents is a prime source of value added. Figure 5.4 shows the original number of innovations graph and the number of innovations divided by real value added in the manufacturing sector. The figure shows a downward slope of the innovation-to-value-added ratio from the early 1990s onwards. With regard to the positive development of value added from that point (figure 5.3), the path of innovation output does not measure up.

Figure 5.4 Innovations (n) and innovations per million SEK value added (1970 constant prices) in the manufacturing sector (n), 1970-2007



Source: Value added: Schön and Krantz 2012.

While it is beyond the scope of this thesis to estimate and discuss the contribution of manufacturing innovation output to GDP, value added, and productivity some brief remarks are appropriate at this juncture. The poor innovation-to-value added ratio from the early 1990s onwards may be interpreted in (at least) two separate ways. The first draws on a linear view of the relationship between innovation and value added, expects constant returns to scale and no major lags. This view is manifest in early endogenous growth models and was discussed in the introductory chapter. This perspective would posit that the strong growth in value added originates from sources other than the kind of innovations studied in this thesis, as the content of such innovation in the value added output is simply lower in frequency. If the discussion is restricted to consider innovation as a source of growth (and hence leaves technical change in a wider sense as well as human capital, reallocation of resources, economies of scale, growing factor inputs etc. aside), plausible sources of the growth in value added could for example include incremental innovations, process innovations, and both systems and service innovations. The literature review in chapter one indicated a growing importance of service in the product portfolios of manufacturing firms. Further, it was noted in chapter four that the nature of service innovations

(intangible with low levels of uniformity and high levels of customization) and their supplementary character raise the risk that they will escape the attention of trade journals. If this is indeed the case, then the degree to which the omission occurs cannot be effectively measured. The same remark applies to system innovations, a growing trend likewise discussed in the introductory chapter. Accordingly, such innovations (together with incremental ones) are poorly represented in SWINNO. Other plausible sources of value added could include innovations and technical knowledge arriving from abroad.[595] Technology and technical knowledge of foreign origin are channeled into Sweden through market transactions (i.e. trade and foreign direct investments) and external spillover effects.[596]

The other possible interpretation of the poor innovation-to-value added ratio is that the relationship between innovation and value added is neither linear nor immediate but subject to significant lags. This view would recognize the effect of all of the above mentioned immediate sources of value added but would additionally argue that those represent the realization of potential in innovations made in earlier decades (i.e. the 1970s and 1980s). Hence, the strong growth in value added is a *lagged* effect of prior developments. This view does not imply that the strong growth is a result from gains related to an unlimited number of prior innovations. Rather, it can be traced to one or a few (domestic and/or foreign) innovations with major application possibilities (i.e. so called general purpose technologies). In this particular case, that one innovation is the microprocessor.

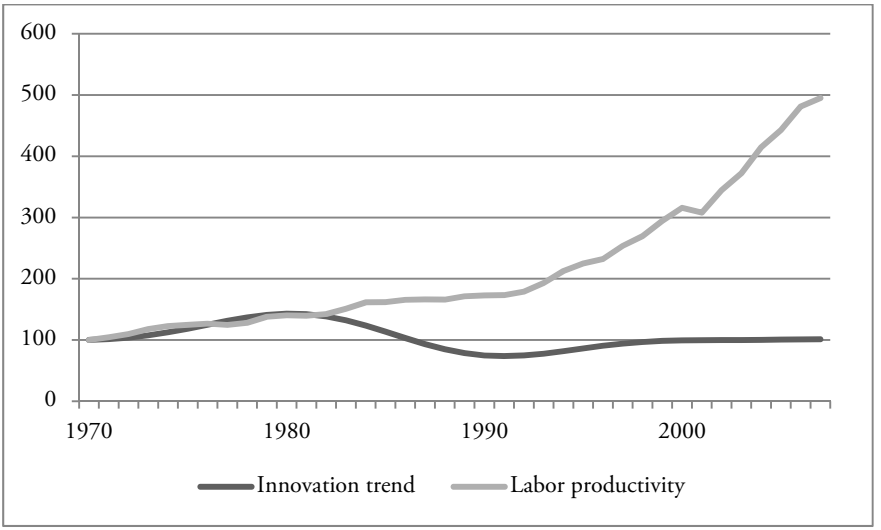
The microprocessor, first launched by Intel in 1971, came to penetrate the manufacturing sector during the 1970s and 1980s. Product development practices, production processes, and product characteristics were revolutionized. It was noted in chapter one that in the 1980s economists around the world were startled by the seemingly absent influence of this revolution on growth. In particular, this remark was made with regard to the poor productivity growth rates observed in the OECD in the 1980s. The positive development of productivity in the 1990s and 2000s (shown in figure 5.5) is experienced not only in Sweden, but throughout the majority

[595] Eaton and Kortum 1999, 2002; Keller 2004; Grossman and Helpman 1991b

[596] See Keller (2004) for a review of the literature.

of OECD countries. In the interpretation framework sketched here, the resumed growth rate is explained by the realization of the potential embodied in information and communication technologies enabled by groundbreaking developments in the early 1970s and 1980s.[597] We are thus referring to a lag length of up to 15-20 years.

Figure 5.5 Innovation trend (n) and labor productivity in the Swedish manufacturing sector (1970=100), 1970-2007



Source: Labor productivity: the U.S. Bureau of Labor Statistics

Potential candidate sources of the positive developments recorded during the 1990s and 2000s are suggested to include human capital formation necessary to complement technology in order to realize its potential, diffusion, the buildup of infrastructure, incremental and complementary innovations directly or indirectly enabled by the microprocessor While chapter four showed that the SWINNO data is indeed driven by ICT innovations in the 1990s and 2000s it also pointed at the risk that a share of

[597] See for example Oliner and Sichel (2000), Jorgenson and Stiroh (2000), Mellander et al. (2005), Gunnarsson et al. (2004), Crafts (2002), and Rhode and Toniolo (2006). Compare with Schön (1990) and David (1990).

such innovations may go unnoticed because they are incremental and/or intangible.

This section has pointed at two different ways to interpret the relationship between the SWINNO innovations and output growth. Both revolved to some extent around the possibility that the strong growth in the 1990s and 2000s partially have sources other than the innovations observed in SWINNO. More attention was paid to the low number of innovations in the 1990s and 2000s than to the high number thereof in the two preceding decades. Chapter four showed that the surge of innovations experienced in the 1970s and 1980s was driven by new machinery and equipment products. As the economic value of the innovations has not been assessed we will have to approach the role of these innovations by other means. One possibility that will be investigated is that the innovations in the 1970s and 1980s represent strategic and technological reorientations rather than immediate commercial successes. Section 5.6 will explore the novelty of the innovations from the point of view of the market and the innovating firm.

5.4 Innovation and R&D

Another manner of exploring whether certain periods are more innovative than others is by relating the innovation count data to some input variable. To this end, R&D expenditure is a particularly relevant variable. Relative to other OECD countries, Swedish business R&D expenditure were merely consistent with the average in 1970.[598] However, genuine takeoff came about in the early 1980s and by 1989 Sweden had advanced to a top position.[599] The increase in resources dedicated to R&D continued and stabilized after the turn of the century 2000 at a level little less than three percent.[600] Regrettably, R&D data prior to 1981 could not be retrieved. However, the increase of R&D investments starts out in the first years of the 1980s and the available data covers the strong increase in R&D expenditures

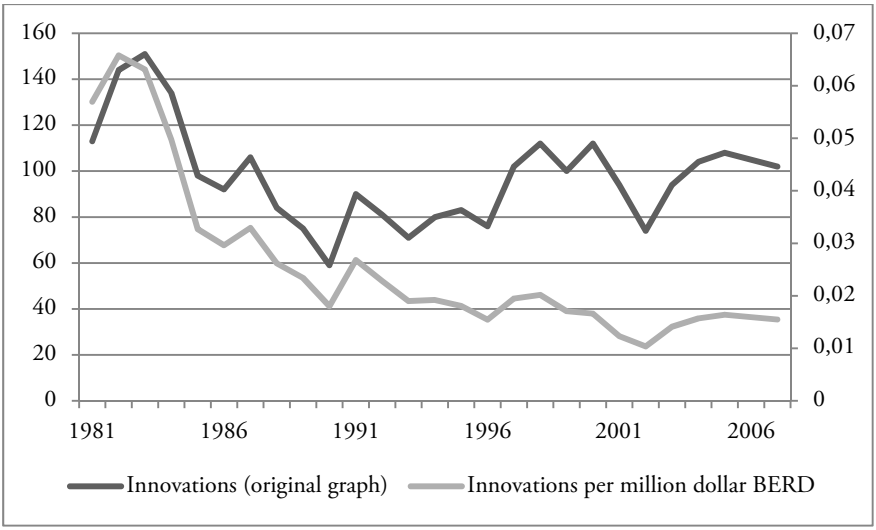
[598] Ohlsson 1992 p. 38

[599] Ohlsson 1992 p. 38ff; Ejermo and Bergman 2013

[600] Ejermo and Bergman 2013. See figure C.1 for the development of business enterprise R&D.

throughout the 1990s.[601] Figure 5.6 shows the original innovation graph and the number of innovations per million dollar business enterprise R&D (BERD).

Figure 5.6 Innovations (n) and innovations (n) per million dollar business enterprise R&D (constant prices), 1981-2007



Source: BERD: OECD. 2005 price level. The OECD business enterprise R&D data contains observations of expenditures every two years between 1981 and 2007. Values for the missing years were retrieved through linear interpolation.

Figure 5.6 shows that R&D is decreasingly productive after the crisis in the early 1990s. One possible explanation of this pattern is that the outcomes of the R&D conducted in the 1990s and 2000s are less well represented in SWINNO. This possibility was already discussed in relation to the development of the innovation-to-value-added ratio.

A second possibility is that while R&D seems to have become decreasingly productive in terms of number of SWINNO innovations, innovations in the 1990s and 2000s may be of higher value than the innovations of the 1970s

[601] Ejermo and Bergman 2013. See appendix C.

and 1980s. Developing cutting edge innovations is likely to require more R&D resources than the development of incremental innovations. This possibility will be returned to in section 5.6.

A third possible explanation of the pattern in figure 5.6 is that expenditures on R&D are frankly, for whatever reason, increasingly unproductive. This possibility invokes a lingering debate surrounding a potential Swedish input-output paradox. This debate is not unique to Sweden, as both the U.S. and Europe at large are also claimed to feature such a paradox in their economies.[602] The Swedish paradox has been formulated in different ways.[603] A set of different asymmetries related to a high level of investment in R&D have been proposed. One is low production and exports of high-tech products.[604] Other formulations of the paradox refer to generally poor productivity and growth performances.[605] The falling number of innovations per million dollar BERD shown in figure 5.6 suggests another formulation of the Swedish paradox: high R&D expenditures and poor innovation outcome of significant innovations.

Outcome dissatisfaction stems from the assumption about the input-output relation underlying early endogenous growth models. These models suggest a constant or increasing returns to scale effect; the more that is put in, the more can be expected to come out.[606] However, assumptions about a symmetrical relationship between input and output have been subjected to much criticism. It has for example been pointed out that the fivefold increase of U.S. scientists and engineers engaged in R&D between 1950 and 1987 found no matching increase in GDP per capita.[607] It seems that R&D

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[602] Ohlsson and Vinell 1987 p. 155; European Commissison 1995; Edquist and McKelvey 1998; Andersson et al. 2002; Dosi et al. 2006

[603] Edquist and McKelvey 1998; Bitard et al. 2008; Ejermo and Kander 2011

[604] Ohlsson and Vinell 1987 p. 155; Braunerhjelm 1998; Edquist and McKelvey 1998

[605] Andersson et al. 2002

[606] For literature pertaining to some of the first endogenous growth models see Romer (1986, 1990, 1994), Grossman and Helpman (1991a, b, 1994), and Aghion and Howitt (1992).

[607] Jones 1995a, 1995b

is subject to diminishing returns to scale.[608] The assumption of a proportional relationship between R&D and innovations is thus unrealistic. As for Sweden, there is no paradox in the relationship between R&D, patents, and value added in slow-growing industries.[609] The only paradox was found in fast-growing industries.[610] These industries had a larger gap between the R&D and value added growth rates and were also less productive in terms of patents. It is argued that maybe the paradox is the cost of growth; growth in fast-growing industries simply seems to cost more in terms of R&D input. Also, firms in fast growing industries may be prone to go down with the so called "bicycle syndrome" discussed in the introductory chapter: one cannot risk investing less in R&D than competitors and hence a positive spiral of R&D investments is engendered. Proposed explanations of the Swedish paradox include poor commercializing competence, a harsh entrepreneurial climate, and an immature venture capital market.[611] However, as regards the dismal innovation-to-R&D ratio in figure 5.6, attention should be paid to large firms as such firms account for the lion's share of R&D investments. The issue of firm size and innovation will be returned to in chapter six.

A fourth possible explanation of the poor development of the innovation-to-R&D ratio is that R&D expenditures to an increasing extent represent growing costs of staying up to date with the international knowledge frontier. This possibility implies that a lot of money is spent on the acquisition of information about the activities of competitors, research results, regulatory changes etc. merely in order to stay competitive.

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[608] Kander et al. 2007; Ejermo and Kander. 2011.This reasoning is contradicted by Braunerhjelm and Thulin (2006) who do find a increasing returns to scale effect; a one percent increase in R&D is related to an approximate three percent increase of the high-tech export-share.

[609] Ejermo et al. 2011

[610] Ibid.

[611] See e.g. Henrekson (2003), Meyerson (1995), Eliasson (2005). These ideas are not new, see e.g. Engellau (1979)

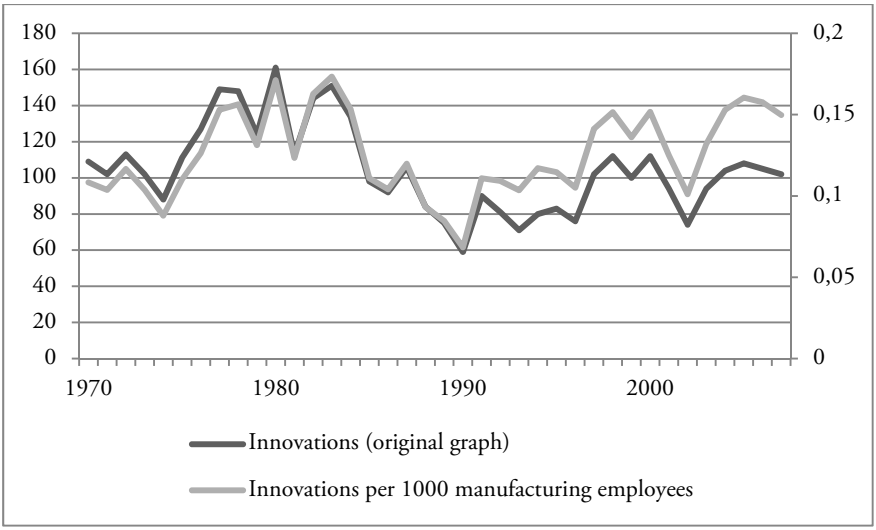
5.5 Innovation and employment

Another input factor relevant to the assessment of innovation output is employment. Between 1970 and 2007 the body of manufacturing sector employees decreased by more than 30 percent.[612] Far-reaching automation and relocation of production to low wage countries has made the Swedish manufacturing sector less labor intensive. As was seen in figure 5.5, this smaller population has managed to bring about a tremendous growth in productivity. Hence, fewer people make more. Does this also apply to innovation?

Figure 5.7 shows the original innovation graph and the number of innovations per 1000 manufacturing employees. It transpires that after having adjusted the innovation count data to employment in the sector the innovation performance is not so dismal after all, the number of innovations per 1000 manufacturing employees in the new millennium approaches that reached in the period 1977 to 1985.

[612] See figure C.2 for the development of employment in the manufacturing sector.

Figure 5.7 Innovations (n) and innovations per 1000 manufacturing employees (n), 1970-2007



Source: Manufacturing sector employment: OECD.

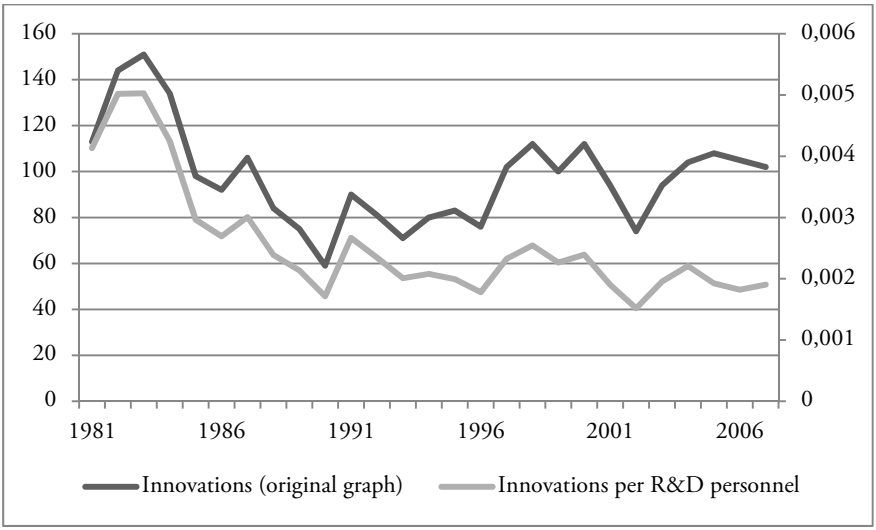
However, there is reason to refute this upward adjustment of innovation output. A simple headcount does not enlighten those interested in questions regarding the innovation activity within firms. The large-scale layoff of blue collar workers seen during the period has left the manufacturing sector with a decimated, albeit more white collar worker intensive body of employees.[613] Instead of exploring the relationship between innovation output and the total number of employees, adjusting output to the number of employees solely devoted to R&D provides a more accurate representation. Between 1981 and 2007, the total business enterprise R&D personnel figure nearly doubled in Sweden.[614] This growth in the number of active R&D personnel

[613] White collar workers are assumed to be the group of employees primarily engaged in innovation activities. However, see e.g. Axtell et al. (2000) for a literature review of shop floor innovation accounts.

[614] See figure C.3 for the development of total business enterprise R&D personnel. Moreover, the pool of people with engineering doctorates and licentiates in which firms could find attractive personnel increased nearly fourfold between 1973 and 2007. The increase is close to linear, there was a decrease in the number of degrees in the second half of the 1970s but

suggests that the prerequisites for innovation should have improved over the period. In figure 5.8 the innovation count data has been divided by total business enterprise R&D personnel in order to assess the outcome of this particular body of employees. If the growth of this group of employees is taken into account, innovation output in the 1990s and 2000s appears in a much worse light than if the total number of manufacturing sector employees is considered (figure 5.7). The upward adjustment is replaced by a downward adjustment.

Figure 5.8 Innovations (n) and innovations per business enterprise R&D personnel (n), 1981-2007



Source: Business enterprise R&D personnel: OECD. The OECD data contains observations of total R&D personnel every two years between 1981 and 2003. Values for the missing years were retrieved through linear interpolation.

The gap between the two graphs in figure 5.8 is not as profound as that between the original innovation graph and the innovations per million

from 1980 the increase develops uninterrupted until 2006 when a slight decrease occurs. See figure C.4.

dollar BERD graph (figure 5.6), though nonetheless significant enough to induce the same concerns and possible explanations that were discussed in relation to figure 5.6.

Sections 5.2 through 5.5 have engaged in four attempts to shed light on the development of the innovation count data from the point of view of important developments in the aggregate economy and the manufacturing sector. The innovation data was put against three output factors; GDP per capita, value added and productivity, and two input factors; R&D and employment. These exercises showed that innovation output was largest during the late 1970s and early 1980s. The early 1990s marks a break in the innovation series; thereafter the output is meager numerically and in relation to both output and input factors. Thus, when it comes to research question one, whether there exists a key period of innovation, the suggested answer at this point is: yes, the key period is approximately 1975 to 1984.

Section 5.6 will look at the development of the novelty of the innovations in order to investigate whether any period exhibits more novel innovations than others. We are particularly interested in whether the fall in innovation output is compensated by a rise in the novelty of innovations or conversely, whether the innovations in the 1970s and 1980s represent technological and strategic reorientations to a larger extent than innovations in later decades.

5.6 The novelty of innovations

Sweden is a small, open economy heavily dependent on exports. Hence, a globally competitive firm population is an important foundation of economic growth. A central component of the Swedish economic slowdown of the mid-1970s was increasing international competition and a weakening of the national competitive advantage. The structural crisis of the late 1970s and early 1980s was thus a period when the overall position of the Swedish economy deteriorated and a need to regain competitiveness became apparent. Truly novel innovations commercialized on a broad front have the potential to make economies relevant again after having fallen behind.[615] In

[615] One of Sweden's largest commercial banks framed the problem in the following way: "A critical cause of the crisis of industry is, aside from the unfortunate development of costs, that

two subsections the extent to which such innovations were commercialized during this (and later) period(s) will be explored.

Two variables in the SWINNO data address the novelty of the observed innovations: market and firm novelty. The market novelty variable is a straightforward measure of whether the innovation is new to the world market. The variable is binary and is based on the information in the trade journal articles. Either the innovation is explicitly stated as being new to the world market or it is not. There is a risk that the number of new-to-the-world innovations is underreported simply because articles omit such information. Over-reporting should not be an issue. The firm novelty variable probes novelty from the perspective of the individual firm and is constructed as a three level categorical variable.

5.6.1 New-to-the-world innovations

A little more than a fifth of all innovations captured in SWINNO were new to the world market at the point of commercialization. Figure 5.9 shows the share of these innovations in total innovation output. The modest share seen in the beginning of the period may be a reflection of the widespread focus on rationalization during the first half of the 1970s that was discussed in chapter two.

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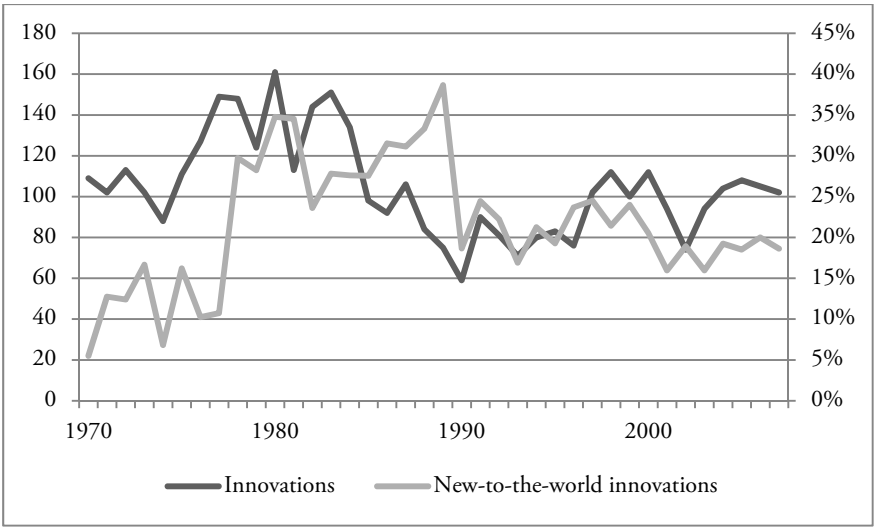
innovation has been neglected for a number of decades. To overcome the crisis these two issues have to be addressed and then brought under control. In a country such as Sweden, a high level of innovation is a prerequisite for both sustained competitiveness and the ability to avoid or alleviate future crises" (Malmström 1978 p. 90, author's translation).

Figure 5.9 Total innovation output (n) and share of new-to-the-world innovations in total innovation output (percent), 1970-2007



While between 1970 and 1977 11 percent (annual average) of the innovations recorded were new to the world market, the share increases to 31 percent (annual average) between 1978 and 1989. In the midst of the structural crisis Swedish firms managed to step up in terms of the development of cutting-edge innovations to a level significantly higher than that of the first eight years of the period or any time again during the 1990s and 2000s. The finding indicates that innovation activity during the structural crisis and throughout the 1980s was geared towards improving on the competitive position on the world market more than in any other period. The share of new-to-the-world innovations is sustained at a high level despite the decrease in innovation output in the second half of the 1980s. This period therefore seems to be the more productive one in terms of such innovations.

5.6.2 Firm novelty

The firm novelty variable complements the market novelty category as innovations may be truly novel albeit not on the world market. An innovation of high firm novelty signals an ambition to significantly alter the

structure of the innovating firm's product portfolio and hence embodies an aim to make it more competitive. The introductory chapter claimed that the majority of firm novelty typologies are dichotomous; either the innovation overturns or reinforces current structures. The SWINNO firm novelty variable was constructed as a three level categorical variable in order to pick up extra nuances of novelty. A spectrum was found to better capture the width and variety of innovations encountered in the trade journals. The firm novelty variable in SWINNO encompasses two different dimensions of novelty; technology and strategy. Hence, the different levels of novelty display a range extending from technological and/or strategic leaps to any related novel increments. Of the innovations recorded in SWINNO 41 percent were highly novel, 44 percent were of medium firm novelty, and 15 percent were of low firm novelty. However, the period conceals a great deal of variation in the distribution of the innovations across the firm novelty spectrum. Figure 5.10 and table 5.1 show the innovations distributed across the three categories of firm novelty during the period.

Figure 5.10 Distribution of innovations across high, medium, and low firm novelty, 1970-2007 (percent)

Table 5.1 Distribution of innovations across high, medium, and low firm novelty, 1970-2007 (percent, period averages)

Period	High	Medium	Low
1970-1975	24.5 (22.8)	56.8 (58.0)	18.6 (19.2)
1975-1982	38.0 (36.5)	44.7 (45.8)	17.3 (17.7)
1982-1990	42.7 (37.9)	46.3 (50.1)	11.0 (12.0)
1990-1994	36.2 (32.0)	52.6 (56.0)	11.2 (12.0)
1994-2007	48.2 (35.1)	36.4 (45.3)	15.4 (19.6)
1970-2007	40.8 (34.2)	44.0 (48.9)	15.2 (16.9)

Note: Innovations from startup firms excluded within parentheses.

As startup firm innovations were categorized as highly novel by default (such innovations are per definition highly novel since the nascent firm does not have a history to relate the innovation to), these innovations are likely to inflate the high novelty share. If the inquiry regards the extent to which the innovations modify the product portfolios of the existing firm establishment, this poses a problem. The distinction was addressed through a subtraction of the startup innovations.[616] Hence, table 5.1 reports the novelty shares both with and without startup innovations included.[617]

The low share of highly novel innovations during the first sub period confirms the picture given in chapter two and the previous section on market novelty, namely that the manufacturing sector was rationalization-oriented during the first years of the 1970s.[618] No other sub period sees as low a share of highly novel innovations and as high a share of low novelty innovations as the period 1970 to 1975. The increase of highly novel innovations in the period 1975 to 1990 resembles the pattern of new-to-the-world innovations; Swedish firms rolled up their sleeves and commercialized innovations of higher novelty during the most intense years of structural crisis and continued to do so throughout the 1980s. The all-time-peak of highly novel innovations after a temporary dip during the years of financial crisis (1990-1994) is largely explained by a marked increase of startup firm

[616] Chapter six engages in an investigation of the development of startup innovations.

[617] Note that figure 5.10 includes innovations from startup firms.

[618] Wohlin et al. 1973 p. 85

innovation.[619] When such innovations are excluded, the period 1982 to 1990 emerges as the one with the largest share of highly novel innovations. Thus, when it comes to transformation driven by existing firms, this is the key period.

All in all, the two novelty variables show that the level of novelty is particularly high during the structural crisis and remains so throughout the 1980s. In this period, the highly novel innovations are primarily the produce of existing firms. Innovations produced in the 1970s and 1980s seem thus to be more novel in a world market perspective and represent technological and strategic reorientations of existing firms to a higher degree than the innovations of later decades. This implies that the poor innovation output observed in the 1990s and 2000s cannot be explained by relatively higher levels of novelty. While the share of highly novel innovations (from the firm perspective) continues to grow after the 1990s crisis, the increase is to a large extent the result of new innovative firms entering the economy. Such firms represent a minor share of total national R&D expenditure.

When it comes to research question number one the previously suggested answer was that the key period of innovation takes place approximately 1975 to 1984. The investigations of the novelty variables suggest a somewhat later period running from the end of the 1970s and continuing throughout the 1980s.

5.7 Triangulation

This first empirical chapter explored the temporal pattern of innovation with regard to both number and novelty in order to answer research question number one: *Was there a key period of innovation and if so, when did it occur?* The findings of the chapter can be placed against received explanations of industrial transformation in Sweden during this period. Chapter three reviewed contributions arguing on the one hand that transformation was stalled during the 1970s and 1980s and those on the other hand that claimed that these decades were indeed ones of intense

[619] Compare 48.2 percent and 35.1 percent.

transformation, particularly so the 1980s and also part of the 1990s. Representatives of the so called Swedish growth school account for the former inference whereas representatives of the challenger; the so called structural analytical research tradition, account for the latter. Of these two inferences, the one suggesting that there was a structural stall in the 1970s and 1980s has gained the widest acceptance.[620] The finding that the main period of innovation occurs in the late 1970s and in the 1980s goes against this view. The protracted surge of innovation after 1975 and during the 1980s and the waning thereof in the 1990s and 2000s fits with the periodization suggested by the structural analytical perspective, albeit the decline in innovation occurs earlier than what would be anticipated by the period characterization. The structural analytical perspective suggests that transformation periods (this particular one dated roughly 1975-1995) typically experience widespread innovation, slow growth, and meager production volumes whereas rationalization periods, (this one starting in the second half of the 1990s and running until the end of the period) witness a decline in innovation, a recovery in growth, and an increase in production volumes. From this perspective, the lack of symmetry found in the trends economic output measures (here GDP per capita, value added, and productivity) and innovation series is no paradox. The innovation count data was divided by value added in constant prices, in order to take into account the growth of the manufacturing sector in the search for more and less innovation-dense periods. Figure 5.3 showed that value added increased modestly in the period 1970 to 1993, made a remarkable take-off in 1994 and grew strongly from thereon and throughout the period. Figure 5.4 showed that the innovations-to-value-added ratio fell in the period of strong value added growth. Moreover, figure 5.5 showed that the innovation series has a trend diametrically opposed to that of labor productivity. Two possible interpretations of these patterns were highlighted for attention. The first assumes immediate effect of innovation upon growth whereas the alternative assumes that significant lags characterize the relationship. The former interpretation draws on early endogenous growth models whereas the latter

[620] As was shown in the beginning of chapter three, this is the view put forth in influential contributions by Olson (1982, 1990, 1995, 1996) and by several Swedish mainstream economists (e.g. Lindbeck et al. 1994, Jonung 1999, Tson Söderström et al. 1994). See Korpi (1996) for a critical discussion of the proliferation of this view.

is common in economic history accounts. Both interpretations posit that SWINNO may not observe the direct sources of the strong growth in the 1990s and 2000s. However, while the former interpretation would emphasize the immediate effect of both innovations of different variety and the adaption and imitation of foreign technology, the latter would suggest that these immediate sources are essentially the lagged result of developments which have taken place in previous decades, in this particular case groundbreaking development in microelectronics. The structural analytical perspective adheres to this latter interpretation. The lag and the shift in innovation character are central parts of this research tradition's narrative. Hence, to the extent that there is an (unobserved) surge in (foreign and domestic) incremental, service, and system innovations in the closing years of the 1990s and 2000s, it would not alter the support lent to the structural analytical periodization of transformation. Incremental innovations (which improve prior products), service innovations (which exploit and add value to prior products), and system innovations (which provide efficiently adapted infrastructure) are indeed suggested to dominate innovation output in so called 'rationalization periods'.

With regard to the relationship between the innovation count data and R&D expenditures and personnel respectively, figures 5.6 and 5.8 showed that the number of innovations per million dollar BERD and R&D staff decreased while these expenditures and this body of staff increased in the 1980s, 1990s, and to some extent also in the 2000s (see appendix C). The cost (in terms of R&D expenditure and personnel) of one innovation of the kind studied in this thesis increased. How does the fall of R&D productivity relate to the received reviewed in chapter three? Regrettably, a lack of data hinders a discussion of the first decade of the period. With regard to analyses of the 1980s provided by the Swedish growth school, they draw on the increasing specialization in R&D and similarly knowledge intense production in the first years of the decade and the subsequent reversal thereof. The fall in R&D productivity may be taken as a confirmation of the inference that there was structural stall in the 1980s; a lot of money was spent, with little return generated. When it comes to the structural analytical perspective, the 1980s and part of the 1990s are characterized as a 'transformation period' which would typically experience innovation output sustained at a high level. Neither the early decline of innovation output nor the early fall of R&D productivity fit with the period generalization suggested by the structural analytical perspective. However, the high level of

innovation novelty sustained throughout the 1980s may indicate that that innovation output was more costly in this period. With regard to the 1990s and 2000s the low R&D productivity (with regard to SWINNO innovations) is in line with the structural analytical model; R&D is argued to be increasingly focused on the rationalization of production, supplementary innovations, and incremental improvements (R&D outcomes not observed in the data at hand). There is also the possibility that increased R&D expenditures are a reflection of increased competition: stepping up spending is one strategy to keep up with, or frog leap 'the Joneses' in a more competitive business climate. It is the cost of being part of the game.[621] Indeed, increased competition is one of the proposed key characteristics of 'rationalization periods'.

Section 5.6 probed the novelty of the innovations. Although they are, given the method of data gathering, all significantly novel to some extent, they were differentiated with regard to market and firm novelty. The finding that few of the innovations in the first half of the 1970s were new to the world market or of high firm novelty fits the picture illustrated in chapter two as well as that given by the Swedish growth school and the structural analytical view. These years saw widespread rationalization and little innovation. The novelty variables reveal that the last years of the 1970s and the 1980s was a period during which the share of new-to-the-world innovations as well as innovations of high firm novelty increased remarkably. The findings lend further support to the period generalization suggested by the structural analytical perspective: innovations were truly novel both in terms of the world market and at firm level during the proposed period of transformation. While table 5.1 shows that established firms largely accounted for the high-novelty innovations during this period, chapter six will delve into the size of the firms behind these innovations.

The degree and nature of novelty embodied in the innovations decrease during the financial crisis in the early 1990s. After the crisis, the market and firm novelty variables behave differently. While the share of new-to-the-world innovations never manages to come close to the levels reached in the 1980s the share of highly novel innovations from the point of view of the

[621] Ejermo et al. (2011) found that a disproportionate relationship between R&D investments and value added characterized fast-growing industries.

firm increases significantly. The reporting of the distribution of innovations across the firm novelty spectrum (with and without startup-firm innovations included) shows that the significant increase is attributable to innovations from startup firms. When startup innovations were excluded, the share of highly novel innovations is lower in the period 1994-2007 than in the period 1975-1990. Of the received analyses of transformation during the period, there seems to be a partial fit of the finding with both Swedish growth school analyses and the structural analytical perspective. The decline of new-to-the-world market and highly novel innovations commercialized by operating firms seem to fit with the period generalization suggested by the structural analytical perspective; 'rationalization periods' produce less novel innovations than 'transformation periods'. The indication that startup firm innovation increases in the last sub period (1994-2007) fits the argument that the institutional reforms prior to and during the financial crisis in the early 1990s engendered startup activity, as put forth by the Swedish growth school.

The next chapter will explore changes in the distribution of innovations across the firm-size spectrum.

6. The innovating firms

While chapter five focused on the distribution and novelty of the aggregate number of innovations, this chapter will explore the characteristics of the innovating firms. The exercise will shed light on the sources of the innovations encountered in the previous chapter.

Firm size is a recurring theme in both the international academic literature on innovation and the Swedish literature spoken to in this thesis. The composition of the firm population preoccupying the domestic debate is influenced by a long-standing international academic discussion about the propensity of different firms to innovate and relatedly, about the role played by firms of different size when it comes to reinvigorating the economy. The objective of this chapter is to answer research question number two: *Did firms of all sizes innovate to the same extent during the period?*

The chapter begins with an investigation of changes in the distribution of innovations across the firm-size spectrum. In section 6.2, the two novelty dimensions discussed in the previous chapter will complement the picture of the firm size locus of innovation. Sections 6.3 and 6.4 deal with innovator concentration and persistence. The investigations conducted in these two sections attempt to illuminate the extent to which the observed far-reaching concentration of R&D translates into a corresponding concentration of innovations in just a few firms.[622] Subsequently, section 6.4 explores a particular dimension of experimentation as it is discussed by Eliasson.[623] Section 6.5 analyzes the findings in light of the received standard narratives presented in chapter three.

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[622] Ohlsson 1992; Hansson and Lundberg 1995; Braunerhjelm 1998

[623] See chapter three, section 3.2.1

6.1 The size of the innovating firms

The innovating firms in SWINNO range from sole proprietorships to multinational firms comprising tens of thousands of employees. 97 percent of all the innovations came from an innovator that could be linked to the firm size data provided by Statistics Sweden.[624] The thesis defines small firms as those with less than 50 employees, medium-sized firms as those with between 50 and 499 employees, and large firms as those with more than 500 employees. Small firms are responsible for nearly half of the innovations, large firms for around a third, and medium-sized firms account for the remaining 16 percent. The distribution of innovations across the firm size spectrum is not very consistent. As can be seen in table 6.2 and figure 6.1, it is subject to significant change during the period.

Table 6.1 Distribution of innovations across firm size classes (number and percent)

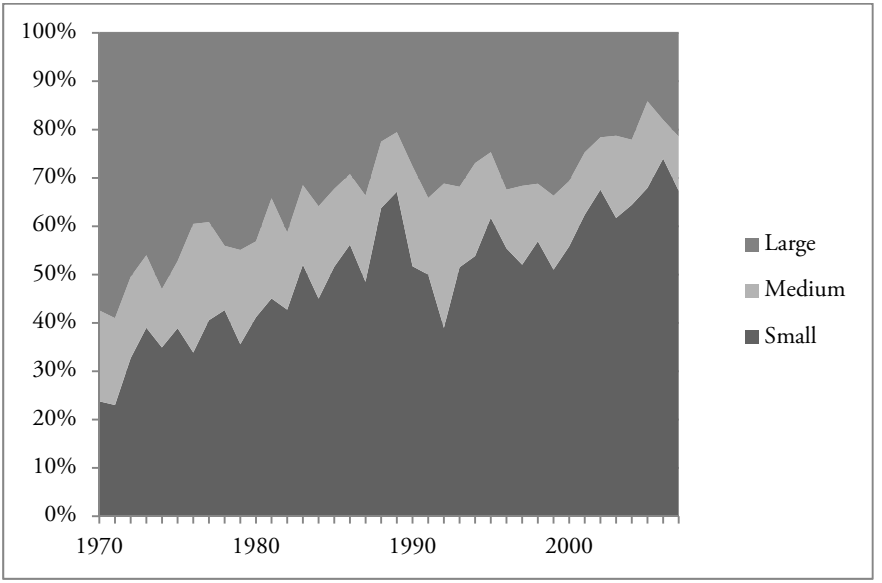
	Small firms	Medium-sized firms	Large firms
Innovations	1887	624	1332
Share	49.1	16.2	34.7

Table 6.2 Distribution of innovations across firm size classes, 1970-2007 (percent, period averages)

Years	Small firms	Medium-sized firms	Large firms
1970-1975	32.1	15.8	52.2
1975-1982	40.1	18.2	41.7
1982-1990	53.2	16.3	30.5
1990-1994	49.2	20.5	30.5
1994-2007	60.9	13.8	25.3
1970-2007	50.1	16.1	33.8

[624] Chapter four discussed the firm data and the choice of at what level to analyze the innovating firms, in particular the multidivisional corporate groups. The discussion resulted in the decision to treat subsidiaries not as independent firms but as belonging to their parent firms in terms of employment.

Figure 6.1 Distribution of innovations across firm-size classes, 1970-2007 (percent)



The primary pattern seen during the period is a shift from large to small firm innovation. This change is fundamental. There is a long-run increase in the share of small firm innovation and a corresponding decrease of that of the large firms. The trends are generally consistent throughout the entire period though there is a temporary fallback of small firm innovation during the financial crisis in the early 1990s. Medium-size firm innovation is the most stable of the three share sizes. SWINNO overlaps with the Wallmark McQueen data for a duration of ten years (see chapter four, section 4.4.1), the latter of which demonstrates that between 1945 and 1980, two thirds of the 100 most important innovations were commercialized by large existing firms while the remaining third were brought to the market by small firms.[625] Furthermore, none of the 100 innovations in the Wallmark

[625] Wallmark and McQueen 1991. The Wallmark and McQueen data defined large and small firms in the same way as they are defined in this study (Granstrand and Alänge 1995).

McQueen data were developed by medium-sized firms. With regard to the period spanning from 1970 to 1980, Granstrand and Alänge report (based on the Wallmark McQueen data) that the share of innovations originating in large existing firms decrease.[626] Fundamental differences between the Wallmark McQueen data and SWINNO aside, the decreasing share of large firm innovation is apparent in both.

Sections 6.1.1 through 6.1.3 will scrutinize the innovation pattern of the three size classes and relate them to the development of the firm population as described in appendix D.

6.1.1 Small firm innovation

The share of small-firm innovations in the total innovation output grows from an annual average of 32 percent between 1970 and 1975 to an annual average of 65 percent between 2000 and 2007. Small firms gain ground between 1970 and 2007 not only in relation to innovations, but with regard to their share of the total firm population.[627] However, the extent and timing of this positive development is contested. The 1970s is coherently depicted as a decade when the number of small firms decreased, and large firms usurped a larger share of manufacturing employment. When it comes to the 1980s, accounts diverge. Some authors show that the number of small firms increased while other report that the number of such firms decreased during the decade.[628] There is a return to consensus in accounts referring to the positive development of the small firm population during the 1990s and 2000s.

The strong growth of small firm innovation in the 1970s shall be contrasted with the reduction of firm population during the same period. Whereas the number of innovating firms is insignificant when compared to total firm population, it is clear that the innovation trend is not just following the population trend. The increase in small firm innovation during the 1970s is

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[626] Granstrand and Alänge 1995

[627] See appendix D.

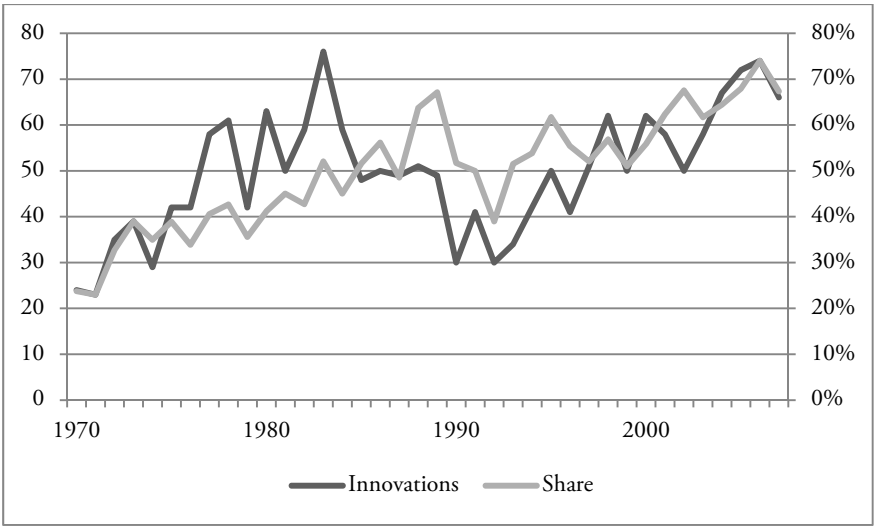
[628] Braunerhjelm and Carlsson 1993; Johansson 1997; Henrekson and Johansson 1997. See appendix D.

thus not solely a reflection of small firm population growth. The increasing importance of small firm innovation (figures 6.1 and 6.2) is, save for a few scattered years, unbroken until the crisis in the early 1990s. Depending on which account provides a more accurate picture of the development of the population of small firms during the 1980s (i.e. whether the number of small firms increases or decreases) the path evolving during this decade is either salient or reflective of population growth.[629]

While the period 1983 to 1990 experiences a drop in the number of innovations, the share of small-firm innovation in the total innovation count continues to increase until 1989 (figure 6.2). The divergence of the two series indicates that although fewer small firm innovations were commercialized during these last years of the 1980s small firms did better than medium and large firms in a time when the number of innovations decreased in general. Conversely, the share drops during the 1990s crisis, which in turn indicates that either or both of the two other size classes fared better in terms of innovation during the downturn.

[629] See appendix D.

Figure 6.2 Small firm innovations (n) and their share of total innovation output (percent), 1970-2007



The remainder of the period witnesses the significance of small firm innovation increase reaching a particularly high level. As seen in appendix D, this period also see a positive development of the small firm population. Section 6.1.1.1 will show that the remarkable increase of small firm innovation after the turn of the millennium is explained by a strong growth of startup firm innovations.

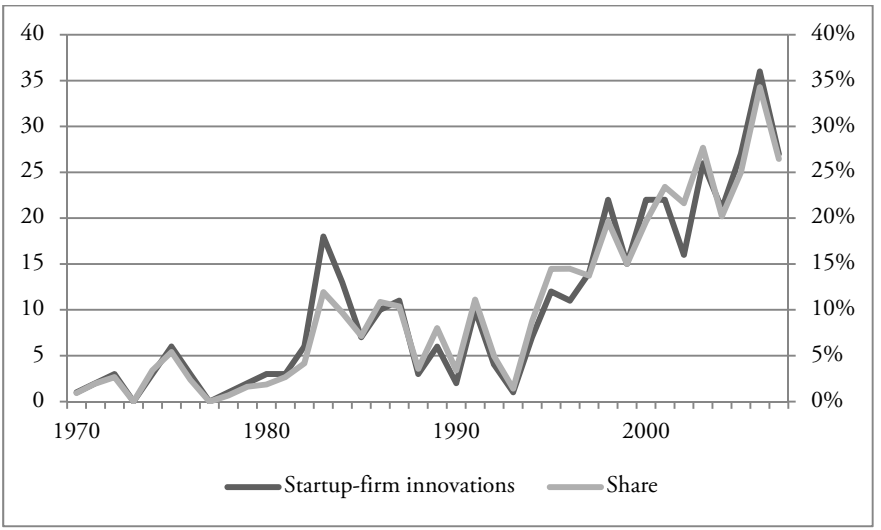
6.1.1.1 Startup firm innovation

Around ten percent of the innovations documented in SWINNO were commercialized by startup firms. Most new firms start small and thus the majority of startup firms can be found in the small firm size class. Only some 5 percent of the startups are found in the medium or large firm size classes. Startup firm innovations in these size classes can be explained by spin offs or mismatches between the years the firm was established,

innovations being observed in a trade journal, and/or by the year for which firm size data was retrieved from Statistics Sweden.[630]

The share of innovations commercialized by a firm which is simultaneously being founded in total innovation output grows from an annual average of two percent between 1970 and 1975 to an annual average of 25 percent between 2000 and 2007. The pattern in figure 6.3 suggests that the full period can be broken into two sub periods with significantly different characterstics; one before and one after the 1990s crisis.

Figure 6.3 Startup firm innovations (n) and their share of total innovation output (percent), 1970-2007



After a non-eventful decade during the 1970s, startup innovations accelerate to reach unforeseen levels in 1983. The increasing share indicates that the numerical growth is "real" in the respect that startup innovation does not merely increase as the total number of innovations increases. The pattern is intriguing given the establishment of the OTC (over the counter) market in 1982 and although no quantitative effect is estimated, this institutional

[630] See Rickne and Jacobsson (1999) for a discussion about the distinction between genuinely new firms and large firm spin outs.

reform may be one potential candidate to help explain the pattern. Although it is by no means the only explanation, the marked increase of startup-firm innovations in the aftermath of the financial crisis in the early 1990s coincides with a similarily striking increase of capital under management by venture capital firms.[631] The strong increase in startup innovations in the 1990s and 2000s stands in sharp contrast to the relatively poor development of those firms in total firm population during the same period.[632]

6.1.1.2 Academic spin-off innovations

Some of the startup innovations could be traced directly to academic research results. Academic spin-off innovations include both innovations commercialized by newly founded firms (so called academic spin-off firms) and innovations developed in universities and research institutes but commercialized by existing firms. Only a segment of the academic spin-off innovations are thus a subset of the startup innovation category. Five percent of the total number of innovations in SWINNO were directly based upon research results from either universities or research institutes.[633] Around half of these innovations were commercialized by academic spin-off firms while the other half were absorbed and commercialized by operational firms. Four universities are outstanding in spearheading innovations: Chalmers University of Technology, KTH Royal Institute of Technology, Lund University, and Linköping University. Together, these four are active in 54 percent of the innovations subsequently commercialized by existing firms and 70 percent of those that result in academic spin-off firms.[634] STFI (Skogsindustrins Tekniska Forskningsinstitut, an industry-owned research institute for wood material research) is the research institute most often involved in innovations commercialized by firms already in business and

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[631] Lerner and Tåg 2013

[632] Appendix D

[633] In addition to these five percent another four percent of the total number of innovations are the result of collaboration between a firm and a research institution (both universities and institutes).

[634] When it comes to collaboration between research institutions and innovating firms KTH Royal Institute of Technology tops the list, Lund University is second, Chalmers University of Technology third, and Luleå University of Technology fourth.

shares first place in the adacemic spin-off firm category with Institutet för Mikroelektronik (a state-owned institute for research in microelectronics).[635] With regard to academic spin-off innovations absorbed by established firms, Alfa Laval, Saab-Scania, and Tetra Pak were the most aggressive and successful commercializers.

Table 6.3 Top four universities in academic spin-off innovation

University	Total	Extant firms	Academic spin-off firms
Chalmers University of Technology	41	18	23
KTH Royal Institute of Technology	31	15	16
Lund University*	31	16	15
Linköping University*	17	5	12

Note: Lund University and Linköping University includes technical colleges. Number five on the list is Karolinska Institutet with nine academic spin-off innovations.

Although only approximately half of the academic spin-off innovations are also startup innovations the two innovation categories develop in much the same way (figures 6.3 and 6.4). However, the two sub categories of academic spin-off innovations behave differently (figure 6.5). While innovations from newly founded firms whose activities are based solely on an academic spin-off innovation see an increase during the 2000s, the number of situations where operating firms commercialize such innovations seem to remain fairly stagnant. The development of the academic spin-off firm innovations mirrors that of startup innovations (figure 6.3) closely. To the extent that institutional reforms during the 1980s can explain the first period of growing volumes of startup innovation such measures may also explain the growth of academic spin-off firm innovations. Still, the increase in academic spin-off firm innovations is not the only driver of the strong increase of startup innovation in the 1990s and 2000s; such firms account for a quarter of all startup innovations between 1990 and 2000 and between 2000 and 2007. It is thus not possible to claim that diligent academic

[635] Skogsindustrins Tekniska Forskningsinstitut merged with Institutet för Förpackningsforskning (Packforsk) in 2003. Together they formed STFI-Packforsk. In 2009, the name was changed to Inventia. Institutet for Mikroelektronik is called IMEGO since 1999.

entrepreneurship alone accounts for the increase in startup innovation seen in the previous section.

Figure 6.4 Academic spin-off innovations (n) and their share of total innovation output (percent), 1970-2007

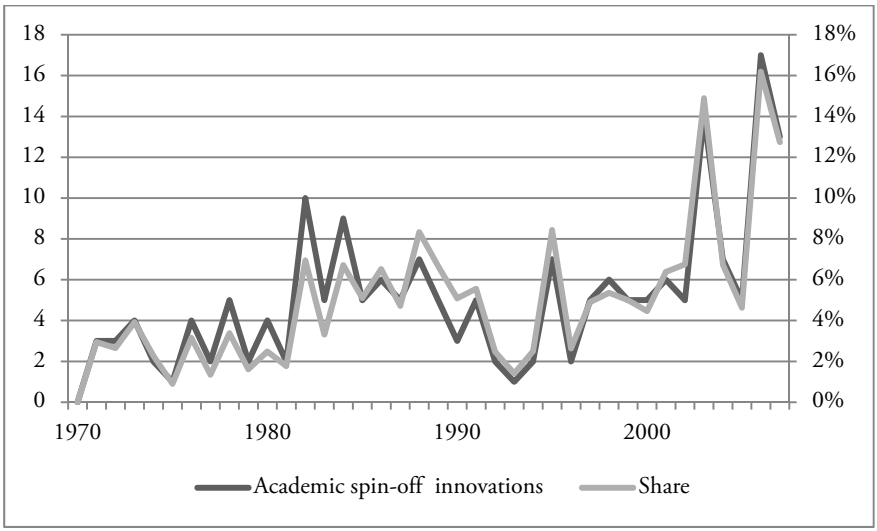
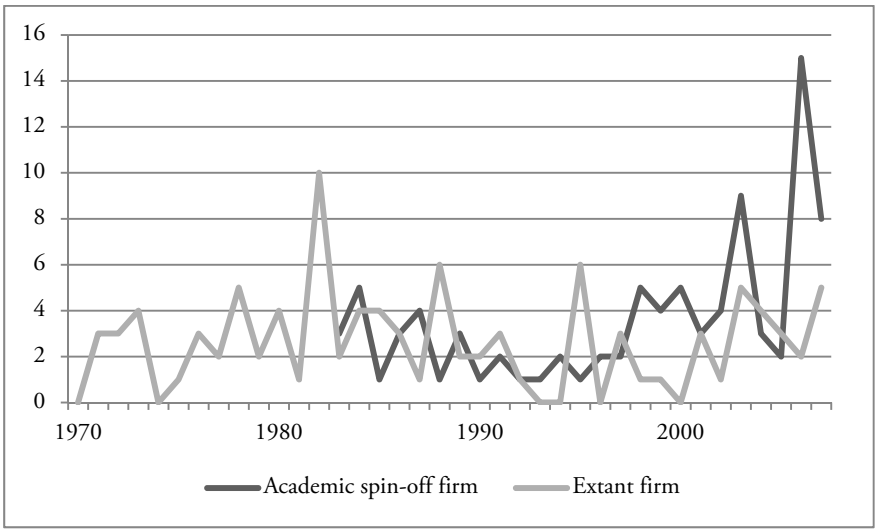


Figure 6.5 Academic spin-off innovations to extant firms and academic spin-off firms, 1970-2007 (n)



6.1.2 Medium-size firm innovation

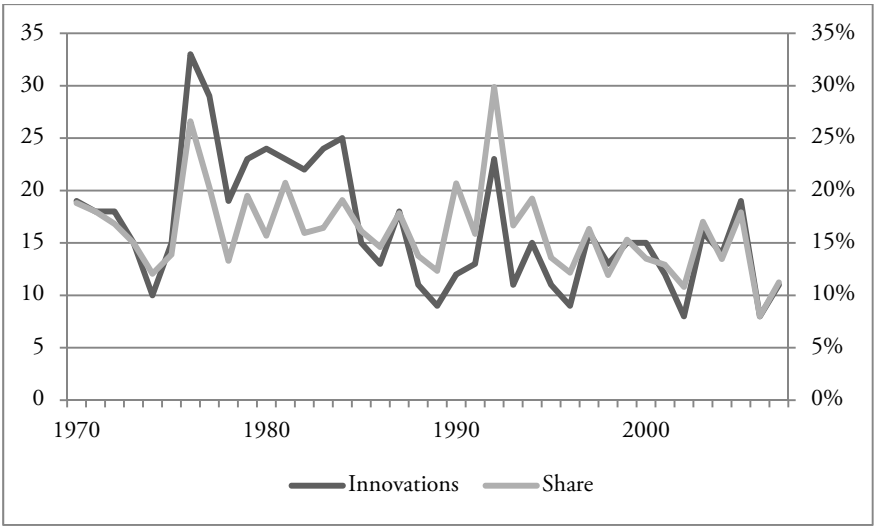
The medium-size firm segment has been described as a "wasp waist" of the body of manufacturing firms.[636] The meager share of medium-size firm innovations depicted in figure 6.1 can be interpreted as a corresponding innovation wasp waist. Appendix D shows that while the 1970s and 1980s seem to have been decades when the the medium firm segment of the total firm population developed weakly, the 1990s and 2000s exhibit more promising signs.[637]

Some 16 percent of the innovations listed in SWINNO were commercialized by medium-sized firms as defined in this thesis (50-499 employees). The share fluctuates somewhat but the trend over the period in its entirety is falling. Between 1970 and 1975 the annual average share of medium size firm innovation is 16 percent whereas the same figure between 1994 and 2007 amounts to 13 percent (figure 6.6). The increasing share during the 1990s crisis suggests that medium-sized firms were more competent at unearthing innovations during these years than were other size groups. Small firms had a falling share during the crisis. The share of large firm innovation will be dealt with below.

[636] See appendix D.

[637] Henrekson et al. 2012

Figure 6.6 Medium size firm innovations (n) and their share of total innovation output (percent), 1970-2007



Taking the positive development of the medium size firm population in the 1990s and 2000s into consideration, the slight decline and the in large parts stagnant innovation trend during these decades appears rather gloomy. While innovating firms represent a negligible share of the entire population of medium-sized firms a simple interpretation of the opposite trends might suggest that the medium-sized firm population is becoming less innovative in the 1990s and 2000s.

6.1.3 Large firm innovation

Large firms have dominated the Swedish economy in the post war period.[638] Appendix D shows that the size of the large firm population is more or less numerically maintained throughout the period. When it comes to manufacturing employment, large firms dominate, though the trend has

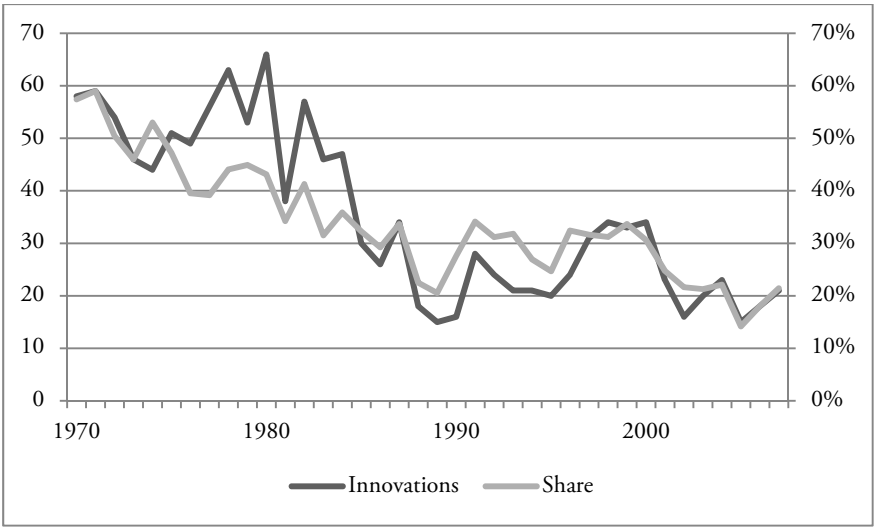
[638] Eliasson 1985a; Swedenborg 1992; Jagrén 1993 p. 77; Schön 2000 p. 414. Henrekson (2003 p. 13) reports that no company among the 50 largest firms in the year 2000 was founded after 1970.

been on a negative trajectory since the 1980s. It has been shown that large firms fared worse than other firm-size segments during the early 1990s crisis, both in terms of job-loss and the closesure of establishments.[639] Chapter two referred to a number of contributions that described the dominance of large firms when it comes to R&D expenditure during the 1970s and 1980s. It has for example been shown that in the beginning of the 1990s four large firms (ABB, Ericsson, Saab-Scania, and Volvo) accounted for 70 percent of the total R&D expenditure in the business sector and the literature reports a contiued dominance of large firms in national R&D expenditure.[640] Considering the strong position of larger firms, the development of the number and share of innovations vis-à-vis other size classes may be seen as dismal. The more or less continuous decline of the large-firm innovation share does simply not correspond to those firms' dominance in the Swedish economy. Figure 6.7 shows a slight increase in the share of large-firm innovations during the 1990s crisis. In spite of extensive cuts, large firms managed to increase their share of innovation output during the crisis years. Taken together, figure 6.2, 6.6, and 6.7 thus appear to indicate that the dip in the innovation count data (figure 5.1) during the 1990s crisis is primarily attributable to a falling number of small firm innovations.

[639] Davidsson et al. 1996

[640] Ohlsson 1992 p. 153; Braunerhjelm 1998; Andersson et al. 2012

Figure 6.7 Large firm innovations (n) and their share of total innovation output (percent), 1970-2007



The absolute and relative decline in large firm innovation is striking given that such firms are of fundamental importance to the Swedish economy. The innovation outcome is especially dismal given that large firms account for such a high share of total business R&D expenditure. Several possible explanations of the poor development present themselves. One is a potential overrepresentation of large firms among the developers of process, system, and service innovations. A growing body of literature reports that business models and innovation strategies of large firms have increasingly come to include tailored systems and services.[641] The increasing complexity of innovations in general and innovations of a systemic character have created the possibility of enhancing product value through the selling of services. A preliminary comment on the relationship between the growing importance of systems and services and the effects that this may have on the empirical results of this thesis was made in chapter five, where it was noted that all of the above mentioned varieties of innovation risk escaping the radar of trade

[641] See e.g. Davies (2004), Henkel et al. (2004), Neu and Brown (2005), and Berggren et al. (2005).

journals. If such innovations go unnoticed to a great extent, and large firms are overrepresented among the developers of them, there is a risk that large-firm innovation is poorly represented by SWINNO. Chapter five discussed whether the poor innovation-to-R&D ratio (in terms of total innovation output) in the 1990s and 2000s could possibly be due to a situation where R&D expenditures have come to include costs of staying up to date with the international knowledge frontier. To the extent that this is a valid explanation, it is particularly plausible when it comes to large firms since they account for the lion's share of R&D expenditure and are, without exception, facing global competition.

Another potential explanation is that trade journals report large firm innovations to a lesser extent than small and medium-size firm innovations. Chapter four discussed this possibility in some depth.

6.2 Firm size and novelty

The objective of this section is to explore the novelty of the innovations commercialized by small, medium-sized, and large firms. In particular, the two subsections attempt to shed light on the type of firms which are the main developers of truly novel innovations. In a wider sense, the section contributes to the international academic debate about the relationship between firm size and organizational search which was discussed in the introductory chapter.

6.2.1 Firm novelty

The firm novelty variable is an assessment of the degree to which an innovation modifies the structure of the innovating firm's product portfolio. Chapter five showed that 41 percent of the innovations documented in SWINNO were highly novel, 44 percent were of medium novelty, and 15 percent were assessed as having low firm novelty. Firm novelty addressed in chapter five was reported both with and without innovations from startup firms as such innovations tend to inflate the share of highly novel innovations. An inquiry addressing the extent to which existing firms modified the structure of their product portfolio through innovation may thus misrepresent the share of such innovations. Section 6.1.1.1 reported

that startup firms were mainly found in the small firm-size class. Hence, in a comparison of the distribution of innovations across the novelty spectrum, the small firm class is likely to emerge with a large share of highly novel innovations due to the element of startup innovation. In order to avoid inflation of highly novel innovations in the small firm category startup innovations were excluded in this particular investigation. In order to be stringent, startup-firm innovations were subtracted from all firm-size categories.

The distribution of total innovation output from each firm-size category across the firm novelty spectrum is displayed in table 6.4. The distribution rates the innovations according to the degree to which they modify the structure of the product portfolios of the innovating firms. The majority of innovations in all size classes are, when observed over the whole period, found in the intermediary (medium) firm novelty category.

Table 6.4 High, medium, and low novelty innovation shares, 1970-2007 (period averages)

	Small firms			Medium-sized firms			Large firms		
	High	Med.	Low	High	Med.	Low	High	Med.	Low
1970-1975	24.1	60.0	16.0	20.4	65.4	14.2	22.6	55.1	22.3
1975-1982	40.9	46.1	13.0	39.1	41.2	19.7	31.4	49.0	19.6
1982-1990	43.7	46.7	9.6	38.6	47.7	13.7	27.2	56.3	16.6
1990-1994	45.4	45.3	9.3	17.1	65.2	17.7	23.0	63.0	14.0
1994-2007	43.8	42.2	14.0	26.5	47.4	26.1	26.1	47.9	26.0
1970-2007	40.8	46.6	12.7	29.7	50.5	19.8	26.9	51.7	21.4

Note: Startup innovations are excluded. 96 percent of all the firm-size coded innovations had a firm novelty code, 95 percent of all small firms and 96 percent of the medium-sized, and large firms.

Over the period in its entirety, small firms have the largest share of highly novel innovation in total innovation output. Furthermore, such firms have the smallest share of low novelty innovations. The innovations developed by small firms are thus, to a greater extent than those developed by medium and large firms, significant modifications of the structure of the innovating firms' product portfolios. Medium-sized firms are ranked second on both parameters while large firms are placed last. Hence, the organizational ecology supposition that large firms search locally and "stick to their knitting" to a greater extent than small and medium-size firms receives

support. Additionally, the finding that large firms search locally to a greater extent than small and medium-sized firms supports results from the Wallmark and McQueen data.[642]

Of the different size classes, small firms see their distribution change the most. The major change occurs between the first two sub periods (1970-1975 and 1975-1982). The high novelty share of small firms gathers momentum when the structural crisis sets in in 1975 and continuously increases until the end of the financial crisis in the early 1990s. Small firm innovation growth in the period 1975-1990 (seen in table 6.2) seems thus to be accompanied by an increase in the novelty of the innovations. With regard to the 1990s crisis, only small firms achieve a retained share of highly novel innovations. It was seen previously that small-firm innovation relapsed during this period, both in absolute and relative terms. However, it seems that in terms of the novelty of the innovations that were commercialized in the crisis, small firms stepped up their game ever more intensely in terms of search and deviated further from current or traditional activities than they ever had during previous or subsequent years. With regard to the last sub-period, none of the other two size classes even come close to the size of the gap between high and low novelty innovations found in the small-firm category. Indeed, the share of high and low novelty innovations in on par in the period 1994-2007 in both large and medium-size firm innovation output.

The positive development of the high novelty share in medium firm innovation comes to an abrupt halt in the early 1990s crisis. Such firms seem not to have been capable of sustaining or generating novelty to the same extent as small firms during the crisis years. Hence, while innovations from medium-sized firms increased during this period (both absolutely and relatively) they tended towards the 'safe bet' variety rather than brave new ventures; medium-sized firms seem to have increasingly reverted to local search during the crisis years.

In general, large firms have the lowest share of highly novel innovations (save for the years of the 1990s crisis) and seem thus to be geared primarily towards minor modifications of the product portfolio structure. However,

[642] See Granstrand and Alänge (1995).

table 6.4 reveals that highly novel innovations increase among this size category during the most intense years of the structural crisis (1975-1982). Moreover, the medium novelty-share decreases less than in the other size classes. This suggests that when faced with falling demand and increasing international competition, Swedish multinationals stepped up in terms of innovation novelty.

Figure 6.8 shows the *distribution of all the highly novel innovations* over the firm size spectrum. The increasing share of highly novel innovations attributed to small firms reflects the growing contribution of small firm innovations to the total amount of innovation output as seen in the beginning of this chapter.

Figure 6.8 Distribution of highly novel innovations across large, medium, and small firms, 1970-2007 (percent)

Note: Startup firm-innovations are excluded from the small firm size class.

This firm-novelty section has revealed some stable patterns. Firstly, small firms have the highest share of highly novel innovations throughout the period. Secondly, of the three size classes, large firms search locally to a greater extent than any other size class. The section has also shown some emerging patterns; the small-firm innovation contribution to the total output of highly novel innovations grows in tandem with the increasing

overall importance of small firm innovation while the opposite pattern is observed in relation to large firms (figure 6.8).

6.2.2 New-to-the-world innovations

The second dimension of novelty investigated in this thesis regards novelty from the perspective of the world market. Figure 5.9 shed some light initially on the temporal distribution of new-to-the-world innovations. The figure showed that the share of such innovations increased significantly during the concluding years of the 1970s and remained at a high level throughout the 1980s, subsequently dropping to lower levels again. New-to-the-world innovations may endow the innovating firm with a first mover advantage and entrepreneurial rents. In addition, such innovations may have positive spillover effects and thus, both directly and indirectly contribute to enhancement of the competitive advantage of the country. This section will explore the extent to which different firm sizes contributed to the tremendous increase pictured in figure 5.9. It also examines changes to the proportion of new-to-the-world innovations in total innovation output of the different firm-size classes.

Figure 6.9 and table 6.5 shows how the portion of all new-to-the-world innovations developed by small, medium- sized and large firms' alters during the period.

Figure 6.9 Distribution of new-to-the-world innovations across firm-size classes, 1970-2007 (percent)

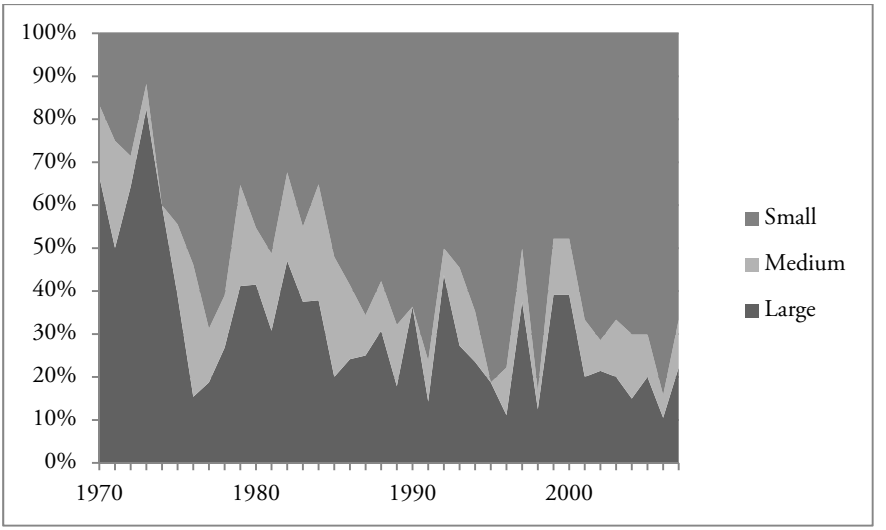


Table 6.5 Distribution of new-to-the-world innovations across firm-size classes, 1970-2007 (percent, period averages)

	Small firms	Medium-sized firms	Large firms
1970-1975	27.7	11.9	60.4
1975-1982	49.0	18.4	32.5
1982-1990	53.1	16.2	30.7
1990-1994	61.8	9.1	29.0
1994-2007	67.7	10.1	22.2
1970-2007	55.0	13.2	31.8

The majority of all new-to-the-world innovations were developed by small firms. The distribution and change therein reflects the overall shift from large-firm to small-firm innovation presented and discussed in the first section of this chapter. There is a positive correlation between the trends in overall innovation and the new-to-the-world innovation: as small-firm innovation increases such companies' share of total new-to-the-world innovation also increases, while large-firms decline in both respects.

While large firms develop the majority of new-to-the-world innovations during the first years of the period, small firms soon overtake them. New-to-the-world innovations during the structural crisis and the subsequent years are to an increasing extent products of small firms. The message is thus that to the degree that new-to-the-world innovations are the vehicles of industrial renewal, small firms were from 1975 onwards engines of this renewal to a greater extent than medium-sized or large firms. However, it is only by regarding the portions of new-to-the-world-innovation by firm-size in total innovation output that we can attempt to gauge the extent to which different sized companies improved their market novelty during the structural crisis. The share of new-to-the-world innovations in the output of small, medium-sized, and large firms is displayed in table 6.6.

Table 6.6 Share of new-to-the-world innovations in total innovation output of small, medium-sized, and large firms, 1970-2007 (percent, period averages)

	Small firms	Medium-sized firms	Large firms
1970-1975	10.0	9.0	14.1
1975-1982	27.6	23.9	20.0
1982-1990	28.9	30.5	28.9
1990-1994	26.6	10.2	19.6
1994-2007	22.6	14.7	17.9
1970-2007	23.8	18.8	20.2

The largest share overall of new-to-the-world innovation is found in the small firm category. During the most intense years of the structural crisis (1975-1982), all size classes experience a growing quantity of such innovations. Furthermore, the proportion increases in all size classes throughout the post devaluation inflationist 1980s. Firms appear to have intensified their investment of resources in cutting edge innovations even though lower relative prices favored exports of products already available. The early 1990s crisis sees new-to-the-world innovation drop across the board, though the small firm category experiences the least pronounced fall. This result resonates with the previously presented finding that small firms manage to retain a large share of innovations that are highly novel from the perspective of the firm during this period. There is a negative trend from 1990-1994 onwards in all size classes except medium-sized firms.

So far, the investigations in this chapter have shown that initial large-firm dominance waned throughout the period. It has been shown that the concentration of R&D in large firms during the 1980s reported in chapter two did not translate into a corresponding concentration of innovations. Rather, innovations are increasingly products of small firms.

Until now, the investigations have considered three aggregates: large, medium-sized, and small firms. However in theory, these classes could be inhabited by one or only a few firms each. Inferences about the distribution of innovations over different firms must discriminate between individual firms. In the following, sections 6.3 and 6.4 will shed light on the issue of innovator concentration and persistence.

6.3 Innovator concentration

A diverse and heterogeneous firm population is widely considered crucial for the development of national competitive advantage and competencies.[643] One way to address the heterogeneity of the population of innovating firms is to investigate the number of firms that contribute to the total number of innovations in a given year. A stylized view on the relationship between innovator concentration and viability would suggest that the more firms that contribute to total innovation output, the more viable the innovation activity of the country.

The Herfindahl-Hirschman (HH) index is a commonly used measure of concentration. The index is based on calculations of each innovating firm's share of the total number of innovations during each year.[644] It is interpreted so that the higher the number, the higher the concentration of innovations in a few firms and vice versa.[645]

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[643] Braunerhjelm 1993 p. 92; Baumol 1990; Wennekers and Thurik 1999

[644] The Herfindahl-Hirschman index is calculated according to the following formula: HHI = $\sum p_i^2$ where p_i is the firm's share of the total innovation output in one year.

[645] The Herfindahl-Hirschman index is typically used to measure the level of concentration in a particular industry. The index is usually based on calculations of the 50 largest firms in the industry. The result from such a calculation ranges from close to zero (perfect competition) to 10.000 (monopoly). The present case included all the innovating firms in the calculation and

Figure 6.10 Innovating firm concentration (HH index) and innovations (n), 1970-2007

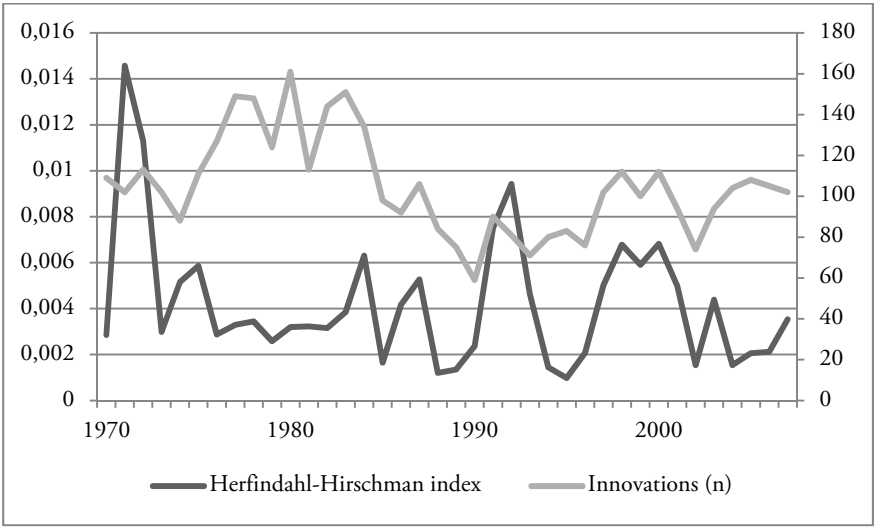

Figure 6.10 shows an irregular concentration index and no sustained trend of increaseing diversity. However, three notable patterns, all occuring in times of crises, or in the period leading up to one, appear in the figure. The first is a marked decrease of concentration from some years into the 1970s until 1983 when the index shows some first signs of recovering again.[646] The low concentration score indicates that many firms rather than an innovative few were engaged in innovation during the structural crisis years. The surge of innovation seems thus to have been a widespread phenomenon and may be a reflection of the growing importance of small firm innovation. The second notable pattern is the high level of concentration during the financial crisis in the early 1990s. Possible explanations could include cuts to the

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thus retrieved values on another scale. In order to take the varying number of innovators into account, the index was normalized according to the following formula: HHI= (HHI-1/N)/(1-1/N) where N represents number of innovating firms.

[646] A decrease with regard to production during this same period is found by Fölster and Peltzman (1997) but whereas the innovator concentration increases thereafter, the production concentration studied by Fölster and Peltzman remains on the same level.

innovation and/or marketing budget due to financial restrictions, a widespread withholding of innovations in anticipation of positive market signals, and/or that the share of innovations coming from the more frequent innovators are maintained throughout while one-time innovators abstain. It can be seen in figure 6.11 that there is an increase in the share of innovations produced by the most active innovators during the crisis years. The third notable pattern is the increased concentration in the years immediately preceeding the turn of the millennium and the accompanying end of the dot.com bubble. The pattern is striking given the strong development of startup innovations during this period. Figure 6.11 shows that while in general innovations produced by the most active firms decrease in these years, Ericsson becomes more prominent. However, the increased concentration cannot be reffered to Ericsson innovations alone but must be seen as a general tendency.

6.4 Persistence in innovation

A growing literature, discussed in the introductory chapter shows that innovation is persistent at the level of the individual firm. The introduction of one innovation at one point increases the likelihood that a sequel innovation will be introduced by the same firm.[647] Given the centrality of innovation to growth, persistence in innovation is a desirable as well as hard-to-beat competitive advantage, for both the individual firm and the aggregate national economy. The most persistent innovators in SWINNO are all large and old multinationals. All of them were established long before the period studied in this thesis. The top four innovating firms are the same as the top four firms in terms of employment in the early 1980s (although in a different order).[648] Together, the ten most persistent innovators account for 15 percent of total innovation output.

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[647] Peters 2009; Raymond et al. 2010; Clausen et al. 2011; Clausen and Pohjola 2012. Previous work has both simulated the positive feedback effects of innovation (Silverberg and Verspagen 2007) and discussed the virtuous circles engendered by R&D and innovation on a theoretical level (Cohen and Levinthal (1989, 1990).

[648] Jagrén 1993 p. 86

Table 6.7 Top ten innovators

Innovation persistence top list	Innovations	Share of SWINNO total
ASEA/ABB (1883)	184	4.6
Ericsson (1876)	95	2.4
Saab (1937)	82	2.1
Volvo (1926)	65	1.6
Sandvik (1862)	39	1.0
Atlas Copco (1873/1898)	37	0.9
Alfa Laval (1883)	34	0.9
Kockums (1840)	32	0.8
AGA (1904)	21	0.5
Pharmacia (1911)	21	0.5
Top ten total	610	15.3

Note: Firm founding year within parentheses. See appendix B for a presentation of how organizational changes in some of the large business groups have been handled.

Asea/ABB and Ericsson were found at the top of the list of innovators in the Wallmark and McQueen data also.[649] However, in this data Astra was found to share second place with Ericsson. Astra accounts for 18 innovations in the SWINNO database while Pharmacia (the other large pharmaceutical company) accounts for 21.[650] A plausible reason as to why the pharmaceutical companies are overtaken by engineering companies is the greater possibility of shortening product development time in the latter type of industry.

The share of the total innovation output developed by the ten most persistent innovators is subject to some fluctuation but declines if viewed over the entire period (figure 6.11). As the top-persistent innovators are all part of the large firm size class, the decline comes as no surprise. The

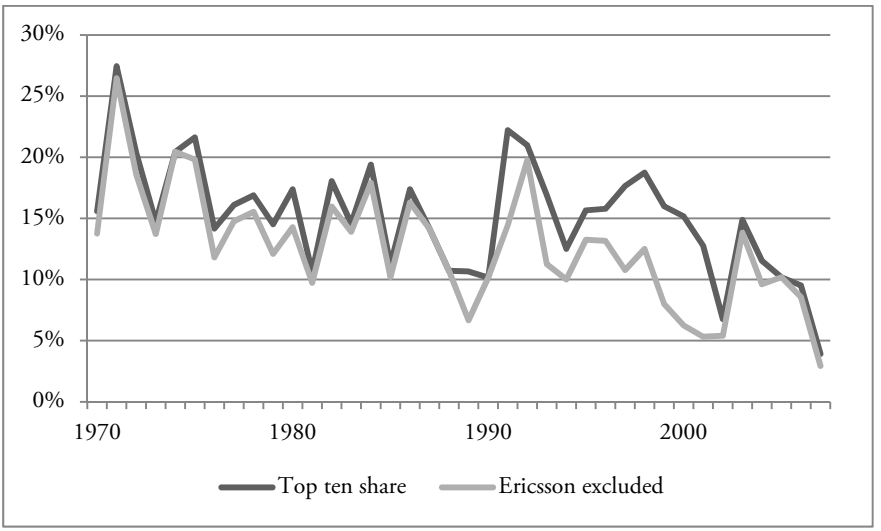
[649] Granstrand and Alänge 1995

[650] According to Granstrand and Alänge (1995) Astra had an R&D intensity of 18 percent while SKF (20 innovations in the database) had one of only one percent (research intensity is given by the R&D/sales ratio).

decrease of this share starts well before the innovation high around 1980. This is an indication that the peak was not primarily driven by the most persistent innovators but rather, as was seen previously, by a large number of innovators.

The increase of this share during the early 1990s crisis is striking given that large firms suffered considerably during these years, in particular with regard to job-loss.[651] A tentative interpretation suggests that while firms less persistent in innovation may have opted for a sustained workforce, the large firms persistent in innovation terminated parts of the workforce in order to sustain innovation in times of crisis. It is apparent that these large, old manufacturing firms positively reassessed their positions and reallocated resources accordingly to areas expected to promote innovation business during the crisis.

Figure 6.11 Top persistent innovators' share of total innovation output with and without Ericsson, 1970-2007 (percent)



The period following the 1990s crisis reveals a marked change in the group of persistent innovators. While the telecommunication firm Ericsson stood

[651] Davidsson et al. (1996), especially chapter 4. See appendix D.

for some 9 percent of the innovations in the above group of firms between 1970 and 1990, it is the by far most important firm from 1991 onwards with a share of 27% percent of the innovations.[652] Ericsson has two innovation peaks, one during the 1990s crisis and one prior to the dot.com crisis in the year 2000. The finding that Ericsson is particularly active prior to the end of the dot.com bubble fits well with the picture given in chapter two. Ericsson suffered acutely when the market for telecom stocks cooled down in the first years of the new millennium. When innovations from Ericsson are excluded, the share of innovations from the most persistent innovators is significantly lower in the 1990s and 2000s.

Given the centrality of innovation to economic growth and the existence of persistence effects of innovation on subsequent innovation, the decrease of innovations from the most persistent innovators may possibly be considered as a sign of a deteriorating basis for national competitiveness. If there is no growth from below, then the long-run competitiveness of the Swedish manufacturing sector may be threatened. Numerous contributions report meager growth of small firms in general and few fast-growing small firms in particular.[653] But, if the persistence in innovation among firms below the leading group increases, there may be less reason to worry about the long-term viability of the competitive advantage of the most important sector of the Swedish economy. The inflow of "new blood" into the system has been argued to be of fundamental importance, domestically as well as internationally.[654] A central aspect of the 'experimentally organized economy' model is experimentation; the combination of factors of production in novel ways.[655] The more experiments there are the more viable the economy is deemed to be. Innovations, widely defined as novel combinations, are first-rate experiments. While in this sense *all* innovations engender experiments, the debut of a new innovator may be seen as the

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[652] Percent of the innovation output produced by this particular group of innovating firms. From 2002 mobile phone innovations are attributed to Sony Ericsson Mobile Communications and are hence not included here.

[653]Davidsson et al. 1996; Henrekson and Johansson 1997; Rickne and Jacobsson 1999; Davidsson and Delmar 2000

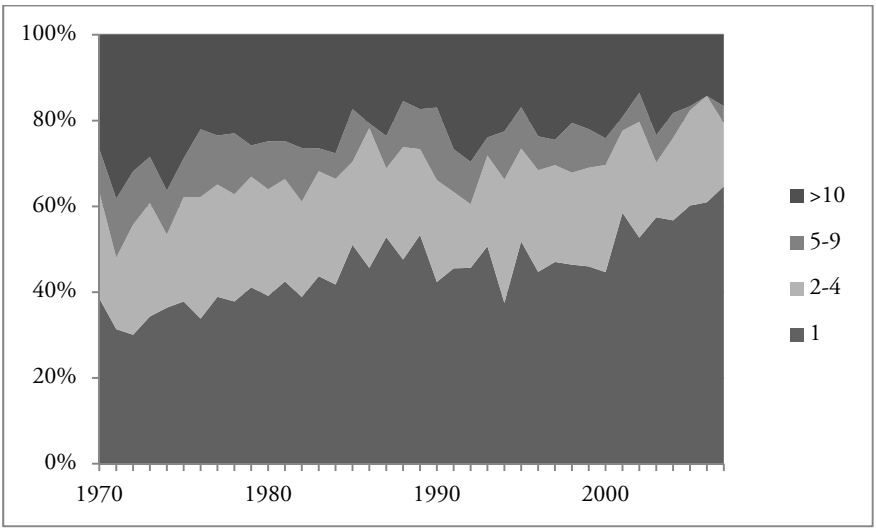
[654] Eliasson 1987a, 1987b; Baumol 1990; Wennekers and Thurik 1999

[655] Eliasson 1991b. See chapter 3, section 3.2.1.

epitome of experimentation. An investigation concerning the extent to which innovations are commercialized by first-time innovators and firms innovating on more occasions is thus one way to approach both the issue of persistence in the total group of innovating firms and indeed the level of first-time experimentation within the economy. The remaining part of this section will engage in such an investigation.

Nearly half of the innovations in SWINNO were commercialized by firms who developed only one innovation while around a quarter were commercialized by firms who had developed more than ten innovations. Figure 6.12 shows the distribution of innovations across this range from innovator 'one-hit-wonders' to the most persistent innovators. Moving downwards in the figure we arrive at the fields where firms are categorized into those innovating on more than ten occasions, on five to nine, on two to four, and those that have innovated on one single occasion.

Figure 6.12 Innovations commercialized by firms innovating on one occasion, two to four, five to nine, and on more than ten occasions, 1970-2007 (percent)



The major trend is a shift from innovations developed by firms innovating on *at least* two occasions to innovations developed by first-time

innovators.[656] Inferences about the innovation persistence of firms innovating towards the end of the period shall take into consideration that first-time innovators (and all other firms for that matter) have had limited time to commercialize a sequel innovation. Any extension of the data to include later years is hence likely to change the relative size of the fields (although the problem will continue to afflict the last years of the period). The increase of first-time innovator innovations in the new millennium reflects the growing importance of startup firm innovation reported in section 6.1.1.1.

Table 6.8 breaks figure 6.12 into sub periods. With regard to the first-time innovators the table shows that there is a steady increase of such experiments all the way up to the financial crisis in the early 1990s. Following slight reversal during the crisis years the positive trend resumes its course again.

Table 6.8 Distribution of innovations across firms innovating on one occasion, two to four, five to nine, and more than ten occasions, 1970-2007 (percent, period averages)

	1	2-4	5-9	10-
1970-1975	34.8	22.5	11.0	31.7
1975-1982	38.8	25.1	11.3	24.9
1982-1990	46.4	23.3	9.1	21.3
1990-1994	44.4	21.2	10.5	23.9
1994-2007	52.1	21.9	6.3	19.7
1970-2007	45.5	22.6	8.7	23.2

From an experimentation perspective, the fact that a growing share of innovation output consists of innovations commercialized by first-time

[656] The chosen approach is not flawless. As a representation of the degree to which innovation output consists of innovations commercialized by first-time innovators, it is relatively uncontroversial but as regards the extent to which these firms contribute to subsequent innovation it becomes more problematic. First-time innovators may be an attractive acquisition for existing firms and thus be brought under the umbrella of a corporate group or merged together with the acquiring firm. In such cases the innovator in question will be ascribed no sequel innovation although it does not stop innovating. Several studies show that acquiring small innovative firms was an important part of large firm strategy during the 1980s (e.g. Eliasson 1985a).

experimenters is a positive development. According to the innovation persistence point of view the finding could provoke the opposite interpretation. From this perspective, the small and declining share of innovations commercialized by firms innovating on five to nine occasions should be particularly troublesome as these firms are presumably those with the most potential to break into the top innovator segment. Traditionally, persistent innovators have been the backbone of the Swedish economy, in terms of output as well as employment.

6.5 Triangulation

This chapter addressed research question number two: *Did firms of all sizes innovate to the same extent during the period?* If there is one distinctive message given by the chapter, it is that the period exhibits a marked shift from large firm to small firm innovation. The increasing importance of small-firm innovation is not a feature of the 1980s, 1990s, or the 2000s, but is rather a trend cutting through the entire period. The finding stands in sharp contrast to the traditional preoccupation with large firms emphasized in the domestic literature. While large firms dominate in terms of R&D and production volumes, small firms seem to account for the majority of innovations and a majority of world-new innovations since the closing years of the 1970s. In general, small firms search distantly to a higher degree than do large firms. This finding resonates the stylized view found in the organizational ecology literature; small firms are more flexible and explorative than are large firms.[657] However, the possibility that there are interactions and links between small, medium-sized, and large firms through for example supply chains should be investigated. As an example, an increase of large firm outsourcing and vertical disintegration could inflate the number and novelty of small and medium-size firm innovations.

With regard to the received accounts reviewed in chapter three, none of them apparently capture the extent of firm development found in the SWINNO data. Swedish growth school accounts generally describe the 1970s and 1980s as decades that are characterized by an institutional climate

[657] Section 1.3.2

that inhibits medium, small, and startup firm investments. This narrative would emphasize that not until credit markets were deregulated and tax policies were reformed (stepwise in the 1980s and leap wise in the early 1990s) was creativity in medium, small, and new ventures set loose. The structural analytical narrative is generally more optimistic about the extent to which small firms, and in particular startup firms, innovated in the 1980s but is not very explicit on the subject.

Assessing the growth of startup innovations prior to the 1990s in the light of Swedish growth school and structural analytical accounts is not easy given that neither of the two research traditions is very specific about the extent of startup activities. What is little and what is much? While Swedish growth school accounts suggest that there is relatively little startup activity, the structural analytical perspective suggests that there is a comparatively large amount. The modest increase of startup innovation in the 1980s (figure 6.3) is certainly an upswing in comparison to the previous decades, but it could hardly be considered a strong increase. However, the strong growth in the 1990s and throughout the period constitutes a significant break with the development of the previous decades. This trend break and strong increase corroborates the picture outlined in some of the recent Swedish growth school accounts. Conversely, the trend break does not fit with the period characterization suggested by the structural analytical perspective. As seen in chapter three the primary characteristics of such periods are rationalization and shake-out rather than startup activity. However, one possible explanation of the increase in startup innovation from the point of view of the structural analysis is that entrepreneurs seize business opportunities that arise as development blocks mature. With regard to this particular period, the expectation would thus be that the majority of the startup innovations since the 1990s crisis were complementary to groundbreaking ICT innovations. Chapter seven will shed light on the industrial origin of startup innovations.

Turning to the development of large-firm innovation, its dismal development stands in sharp contrast to the economic dominance of such firms. The finding that large-firm innovation wanes throughout the period refutes any idea that the lion's share of Swedish industrial creativity is tied up in large firms. When it comes to the character of the innovations commercialized by large firms, it was shown that innovations were found in the vicinity of prior products to a greater extent than in any other size class. However, the share of large firm innovations that were considered new to

the world market increased significantly in the period 1982 to 1990. Swedish growth school accounts are split on the issue of whether large firms undertook the renewal requisite to reinvigorate the industrial structure in this post devaluation period. On the one hand there is plentiful anecdotal evidence to suggest successful reorientation in firms in industries other than the crisis-ridden ones. On the other, there is the inference that subsidies and the sharp devaluation in 1982 reduced incentives to reorient firms in crisis-ridden industries. The reversal of specialization in R&D and similarly knowledge-intensive products is taken as a sign of structural lock-in. Given the large firm dominance in R&D expenditure, this reversal is by and large ascribed to such firms. The structural analytical narrative describes the second half of the 1970s and the 1980s as decades where profound restructuring of large firms took place, both in terms of products and processes. This inference encompasses reorientation in firms directly hit by crisis as well as those that escaped it. While some crisis-ridden firms were wiped out, the surviving ones reinvented themselves through process development and product specialization. While this chapter does not make any distinction between large firms in different industries, the finding that the new-to-the-world innovation share increases remarkably in the period 1982 to 1990 seems to indicate that the development of groundbreaking innovation is fairly widespread throughout this firm-size segment. The diverging views regarding the extent to which crisis-hit firms reorganized during the structural crisis makes it essential to investigate the industry origin of the innovations that were commercialized during this period. Chapter seven undertakes such an investigation.

Concerning the investigation of the development of innovator concentration no obvious trend emerged. The concentration index moved both downwards and upwards during the period. However, the pattern found with regard to the structural crisis (1975-1982), the financial crisis in the early 1990s, and the period leading up to the turn of the millennium suggests support to the structural analytical perspective. The widespread innovation activity in the period of intense structural crisis (1975-1982) is not indicative of the structural stall suggested by the Swedish growth school to characterize the period. Rather, the finding that a lot of different firms seem to have been involved in renewal suggests that innovative actors across the economy contributed to creativity and innovativity during this period. By and large, this finding fits with the character of a transformation period as it is described by the structural analytical perspective. The increasing

concentration of innovation prior to and during the financial crisis seems also to support the structural analytical view that this period is one during which creative destruction intensifies. Fewer firms find it feasible to pursue innovation. The return to low concentration after the crisis may be interpreted as a clearing of ground for a new wave of widespread innovation. The increasing concentration from the mid-1990s until a few years into the new millennium fits with the structural analytical characterization of a so called 'rationalization period'. The model suggest that during such periods, rationalization start to crowd out transformation as the dominating force In the event that this characterization also entails fewer innovating firms (which is not altogether clear), the relatively high level of innovator concentration in the closing years of the 1990s is according to expectations. Given that rationalization is augmented in the new millennium, the increased diversity of innovating firms during these years comes as a surprise. However, the structural analytical narrative leaves room for the possibility of a 'new face' of rationalization, e.g. increasing importance of small firms thanks to vertical disintegration and outsourcing, in turn enabled by new technology and practices.

Low innovator concentration is the ideal of the' experimentally organized economy' model. A diverse and changing innovator population is a central component of a viable economy. Among other things, widespread innovation is a function of both the extent to which markets are allowed to coordinate experimentation and the degree to which insitutions and policies are fit to ensure this. According to this line of reasoning, the deregulations, tax reforms, and facilitation of entry during the 1980s and 1990s should have paved the way for an increased number of innovators. No clear such trend is evident, regarding neither to innovator concentration (figure 6.10) nor one-time-innovators (figure 6.12); concentration fluctuates while the share of innovations commercialized by one-time-innovators increases in the 1980s, levels off in the 1990s, and rebounds again after the turn of the millennium.

The next chapter will explore changes in the structural composition of total innovation output in order to shed light on the industry origin of the innovations observed in this and the preceding chapter.

7. The structural composition of innovation output

While chapter five explored changes in aggregate innovation output and some of its characteristics chapter six took a closer look at the innovating firms. The present chapter addresses changes in the structural composition of innovation output and the characteristics of innovations developed in industries on the positive and on the negative side of transformation. The main purpose of the chapter is to answer research question number three: *Was there an observable key period of change in the structural composition of the innovation output and if so, when did it take place*? Before coming to potential changes, the distribution of the full period of innovation output across industries is presented and discussed in brief.

7.1 Distribution of innovations across industries

The 3978 innovations commercialized in the period are distributed over 22 industries.[658] Table 7.1 shows a clear dominance of capital goods in total innovation output. The majority of the innovations are found in highly value-adding engineering industries such as machinery and equipment, instruments, and radio, television, and communication. In the literature, these industries are commonly denoted 'high-tech' whereas industries with a lower number of innovations in table 7.1 are commonly denoted 'medium-low' and/or 'low-tech' (e.g. textiles, wood, pulp, paper, rubber etc.).[659]

[658] 24 industries if tobacco is separated from food and beverages and the apparel industry is separated from textiles.

[659] Hatzichronoglou 1997

Table 7.1 Number of innovations in different industries and their share of total innovation output

SNI	Industry	Innovations	Share
15t16	Food, beverages, and tobacco	71	1.8
17t18	Textiles and apparel	27	0.7
19	Leather and footwear	3	0.1
20	Wood and wood products	65	1.6
21	Pulp and paper	58	1.5
22	Coke and refined petroleum products	3	0.1
23	Printing and publishing	6	0.2
24	Chemicals, chemical products, and man-made fiber	157	3.9
25	Rubber and plastics	194	4.9
26	Non-metallic mineral products	34	0.9
27	Basic metals	92	2.3
28	Fabricated metal products except machinery and equipment	210	5.3
29	Machinery and equipment	1175	29.5
30	Office machinery and computers	246	6.2
31	Electrical machinery and apparatus	180	4.5
32	Radio, television, and communication equipment and apparatuses	283	7.1
33	Medical, precision, and optical instruments, watches and clocks	597	15.0
34	Motor vehicles, trailers, and semi-trailers	143	3.6
35	Other transport equipment	90	2.3
36	Other manufacturing	32	0.8
72	Computer and related activities (software)	220	5.5
74	Technical consultancy and testing	92	2.3
Total		3978	100

Note: Innovations refer to the total number of innovations developed in the industry. Share (percent) refers to the industry's share of total innovation output.

The low, medium, and high tech classification is based upon the technology intensity of industries which is in turn based upon both their R&D intensity and R&D embodied in intermediate and investment goods.[660] In practice however, there has been a somewhat biased focus towards R&D intensity rather than the embodiment thereof. Hence, high technology intensity is taken to go together with high R&D intensity and low technology intensity with low R&D intensity. Several academic observers argue that these habitual associations are fallacies.[661] The criticism pertains to the implicit acceptance of a *linear* or *sequential* model of innovation, were R&D is the step that naturally precedes innovation. According to this line of thought low R&D intensity should imply fewer innovations.[662] The major criticism of this idea is based upon findings regarding the character of knowledge-creating activities and innovations in so called low and medium- tech industries. It has been argued that the innovation activity of these two categories of industry differs from that of high-tech industries.[663] With regard to the drivers of innovation in low-tech industries demand side factors as well as the supply of new production process technology from other industries have been highlighted whereas innovation output in turn has been suggested as being dominated by incremental innovations (i.e. product differentiations) and new processes.[664] Regrettably, these types of innovations are ones that are rarely noted by the radar of trade journals. This would apply to incremental innovations because there are simply too many and there is insufficient news value and new processes are likewise affected because they are often held secret. As a result, innovations in low and medium-tech industries are likely to be underreported in SWINNO.

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[660] OECD 1986

[661] See e.g. Smith (2001), von Tunzelmann and Acha (2005), Hirsch-Kreinsen et al. (2003), and contributions in Hirsch-Kreinsen et al. (2005).

[662] Smith 2001; Hirsch-Kreinsen et al. 2003

[663] Hirsch-Kreinsen 2008

[664] von Tunzelmann and Acha 2005; Hirsch-Kreinsen 2008; Laestadius 1998

7.2 The structure of innovation output: major trends

This section explores the key changes in the structural composition of total innovation output. The absolute number of innovations commercialized each year is omitted to shift the emphasis instead to each industry's relative contribution to each year's total innovation output. In summary, only those industries leaving major contributions to total output see their shares change significantly. Minor changes in industries making only peripheral contributions are therefore left unreported.

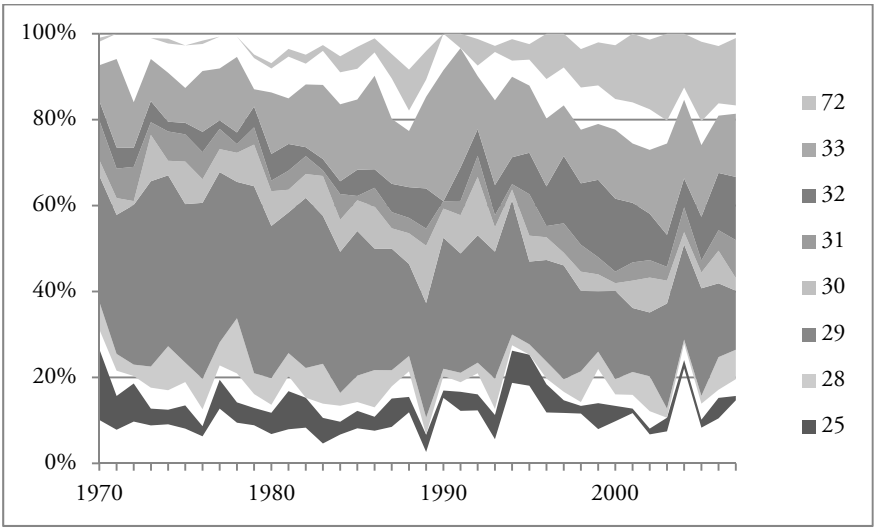
Figure 7.1 provides a broad picture of how the structure of innovation output oscillates over the period. The major change is the dethroning of machinery and equipment innovations which enjoyed initial dominance and the growth in radio, television, and communication equipment, and software innovations.[665] Instrument innovations also increase during the period, albeit less than those mentioned above. All of these increasingly innovative industries are closely related to the microelectronic revolution, as exploiters of microelectronics and to a lesser extent as developers thereof. The share of microelectronic components in total innovation output is negligible. The SWINNO data seems thus to suggest that the Swedish manufacturing industry was rather an applier or microelectronics more than a supplier thereof. However, to the extent that manufacturing firms both develop *and* apply microelectronics, pure microelectronic innovations may be underreported. A case in point is Ericsson whose subsidiary Ericsson

[665] Another way to present this increasing diversity of industries contributing to total innovation output is through a Herfindahl-Hirschman index, see figure E.1. The increase in radio, television, and communication innovations takes off around 1994/1995. The strong growth following these years warrants a cautionary remark since the only specialized telecom journal (Telekom Idag) included in the database was established in 1994. The birth of a specialized journal is argued to represent both an increase in the supply of material to write about and an increase in the demand for informed reports. Hence, the start of Telekom Idag is argued to represent dynamic developments in this industry. However, Telekom Idag shall not be endowed with a disproportionately large amount of influence on the total number of innovations since other journals also report on the development of this industry (e.g. Elektroniktidningen and Ny Teknik).

Components (later Ericsson Microelectronics) developed microelectronic hardware that became part of the architecture of Ericsson products.

Moving downwards in figure 7.1 we arrive at 'Computer and related activities' (SNI 72), 'Instruments' (SNI 33), Radio, television, and communication equipment and apparatus' (SNI 32) etc.

Figure 7.1 The eight industries with the largest share of total innovation output, 1970-2007 (percent)



Note: Only the eight largest industries (in terms of contribution) are highlighted; 'Rubber and plastics' (SNI 25), 'Fabricated metal products' (SNI 28), 'Machinery and equipment' (SNI 29), 'Office machinery and computers' (SNI 30), 'Electrical machinery and apparatus' (SNI 31), 'Radio, television, and communication equipment' (SNI 32), 'Instruments' (SNI 33), and 'Computer and related activities' (SNI 72).

7.3 Microelectronics in innovation output

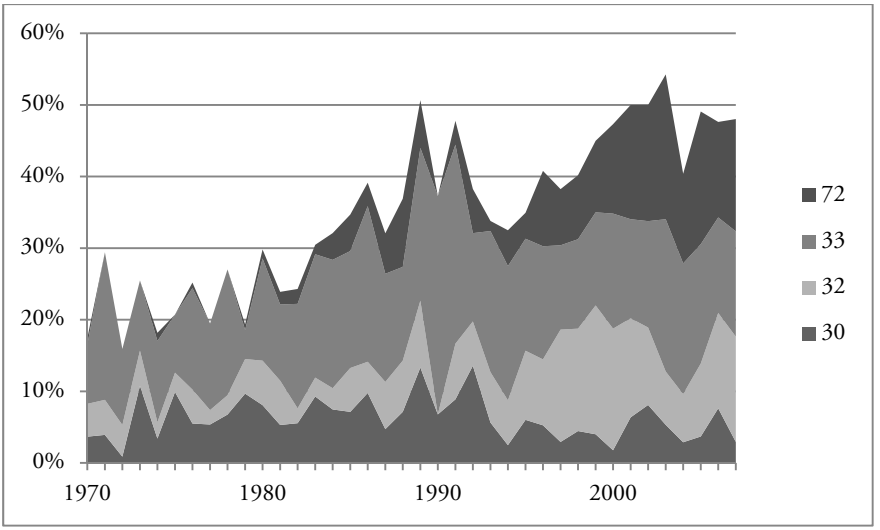
The development and diffusion of microelectronics encompasses most aspects of manufacturing. During the course of the last 40 years the sector has transformed with the assistance of computers, telecommunication, microelectronic-based instruments, and software. Given the manner in which microelectronic-based technology has penetrated development and

production processes, the majority of innovations in SWINNO are in some way related to microelectronics. However, henceforth this section will focus on the innovations that enabled the abovementioned transformation. More than any other innovations, those in office machinery and computers, radio, television, and communication equipment, instruments, and software have catalyzed and indeed characterized this revolution.[666] The industries will henceforth be referred to as 'microelectronic-related' industries. 34 percent of all innovations in SWINNO fall into these four industry categories.

Figure 7.2 displays the development of innovations in these four microelectronic-related industries as a two-stage process. The first period of major change occurs in the 1980s as the proportion of innovations from the four industries in total innovation output increases from a period average of 24 percent between 1975 and 1982 to a period average of 35 percent between 1982 and 1990. Following a significant decline during the 1990s crisis of such innovation types, a second period of major increase takes off in 1994 and lasts until the turn of the millennium. The period average share of innovations in microelectronic-related industries between 1994 and 2007 is 44 percent.

[666] The delimitation is similar to that in Johansson (1999a).

Figure 7.2 Innovations in microelectronic-related industries, 1970-2007 (percent of total innovation output)



Note: The figure regards 'Office machinery and computer' (SNI 30), 'Radio, television, and communication equipment and apparatus' (SNI 32), 'Instrument (SNI 33), and 'Software' (SNI 72) innovations.

Table 7.2 shows that instrument innovations and, to a lesser extent, software innovations account for the first surge. The instrument innovations of the 1980s increasingly come to embody microelectronics. The growing importance of such technology in instruments is apparent in trade journal articles as the use of terms such as "microcomputer-based" and "computerized" multiply during the decade. The second surge of innovations in microelectronic-related industries is attributable to radio, television, communication equipment and software innovations. In 1999 radio, television, and communication equipment innovations account for 18 percent of the innovations in the total output figure whereas in 2003 and 2005 software innovations account for as much as 20 percent of the total. Radio, television, and communication equipment innovations decrease significantly after the turn of the millennium but recover in the concluding years of the period.

Table 7.2 Share of innovations in microelectronic-related industries in total innovation output, 1970-2007 (percent, period averages)

Period	30	32	33	72
1970-1975	5.4	4.0	11.5	0.3
1975-1982	7.0	3.9	11.9	0.8
1982-1990	7.9	4.6	18.6	4.2
1990-1994	7.5	5.4	21.8	3.2
1994-2007	4.6	11.9	15.5	12.2
1970-2007	6.2	7.4	15.4	5.9

Note: 'Office machinery and computers' (SNI 30), 'Radio, television, and communication equipment' (SNI 32), 'Instruments' (SNI 33), and 'Software' (SNI 72).

7.4 Innovating firms in microelectronic-related industries

Chapter six found that with regard to the entire data set, small-firm innovation dominates from the closing years of the 1970s onwards. The increase in such innovations continues uninterrupted with the exception of a slight reversal during the 1990s crisis. In order to elicit differences between the size distribution of innovators in the four microelectronic-related industries and the distribution of innovators in other industries the data was split in two. Innovators in microelectronic-related industries thus constitute one group whereas innovators in all those remaining industries comprise another.[667]

[667] 97 percent of the innovations in the microelectronic-related industries and 96 percent of the innovations in the remaining industries were matched with firm-size data from Statistics Sweden.

Table 7.3 Innovator size distribution in microelectronic-related industries, 1970-2007 (percent, period averages)

Period	Small	Medium	Large
1970-1975	30.4	15.6	54.0
1975-1982	38.0	17.2	44.8
1982-1990	59.0	16.0	25.0
1990-1994	56.2	13.9	29.9
1994-2007	69.8	10.8	19.4
1970-2007	55.1	13.8	31.1

Table 7.4 Innovator-size distribution in remaining industries, 1970-2007 (percent, period averages)

Period	Small	Medium	Large
1970-1975	32.7	15.8	51.5
1975-1982	40.3	18.6	41.1
1982-1990	50.4	16.4	33.2
1990-1994	45.5	24.4	30.1
1994-2007	53.4	16.4	30.2
1970-2007	46.4	17.7	36.0

Viewed over the entire period the predominance of small-firm innovation is larger in microelectronic-related industries than in the remaining industries. Conversely, the large firm share is smaller in the former type of industries compared to the latter. Furthermore, a lower amount of microelectronic-related innovators are of medium size. However, when broken into sub periods, the data reveals that the small firm share in microelectronic-related industries lags slightly behind that of the remaining industries until the period 1982-1990. Microelectronic-related industries were thus no precursors to small firm innovation. The 1980s see a profound change take place in the innovator structure of microelectronic-related industries as small-firm dominance replaces the large-firm dominance of the prior

period.[668] In the last sub period, small firm innovation in microelectronic-related industries explodes and reaches an especially high level. It shall be seen in the following section that the enormous growth of small-firm innovation after 1994 is caused primarily by an increase in startup innovation. The share of small firm innovations in microelectronic-related industries between 1994 and 2007 would have been even higher had the size of firms innovating in radio, television, and communication equipment not have dragged the mean value down. In this period, 79 percent of the innovators in office machinery and computers were small, 76 percent of those in instruments, and 77 percent of those in software, while only 50 percent of the innovations in radio, television, and communication equipment were commercialized by small firms. The sizeable portion of large firm innovation in the latter industry is a reflection of the important role played by Ericsson. The firm accounts for 24 percent of the total number of innovations in the radio, television, and communication equipment industry with 20 percent of them occurring during the last sub period.

With regard to medium-sized firms there seem to be a more pronounced small and large firm polarization among the innovators in the microelectronic-related industries than in the remaining ones.

7.4.1 Microelectronic-related startup innovation

Chapter six reported a remarkable increase in the share of innovations commercialized by startup firms after Sweden emerged from the crisis in the early 1990s. Of the 396 startup-firm innovations in total innovation output, 215 (54 percent) took place in microelectronic-related industries. These industrial fields seem thus to be housing a considerable share of the innovative startup firms represented in SWINNO. When broken into sub periods it transpires that the concentration of startup innovations in microelectronic-related industries is a recent phenomenon.

[668] A corresponding shift takes place in the group of remaining industries.

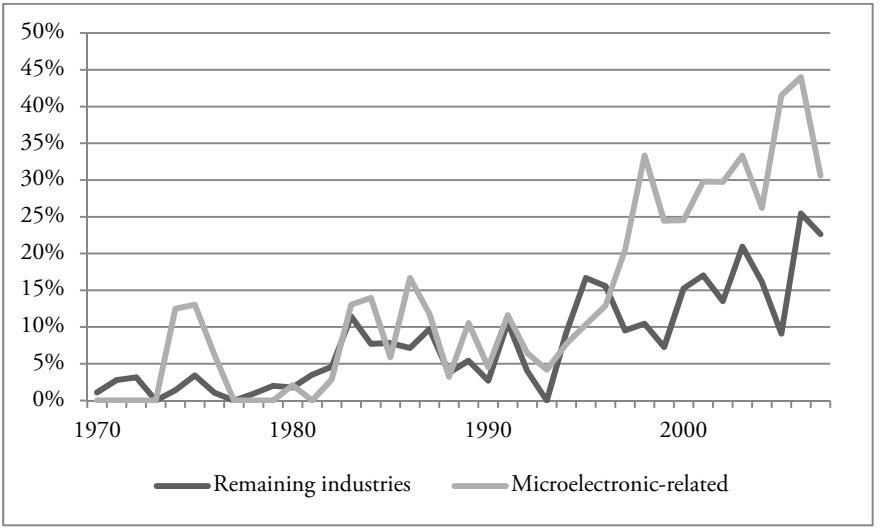
Table 7.5 Startup innovation found in microelectronic-related industries and in remaining industries, 1982-2007 (percent, period averages)

Period	Microelectronic-related industries	Remaining industries
1982-1990	41.2	58.8
1990-1994	55.7	44.3
1994-2007	56.9	43.1

Note: As startup-firm innovations prior to the 1980s were scarce the periods 1970-1975 and 1975-1982 were excluded from the table.

Another way to approach the prevalence of startup innovation in the two industry groups is by looking at their level of startup innovation intensity. 16 percent of all innovations in microelectronic-related industries were commercialized by startup firms while only 7 percent was the equivalent figure for the remaining industries. The startup innovation intensity of the microelectronic-related industries achieves a first time high in the middle of the 1970s.

Figure 7.3 Startup intensity in microelectronic-related and remaining industries, 1970-2007 (percent)



This relative increase is due to a low total number of innovations (compared to that in the other series) but it nonetheless represents the first innovations by startup firms in the microelectronic-related industries and as such it

warrants some attention here. Five firms account for the increase, the most renowned of which is Selcom. Selcom was founded in 1974 to launch a cutting edge photo detector-based position sensor developed by Lars Lindholm and Göran Pettersson at Chalmers University of Technology. The electro-optical Selspot system found a wide range of applications over the years; measuring the movement of jet pilots when in cockpit, analyzing the deformation of ship hulls, and assessing golf swings.[669]

Apart from the occasional increase in microelectronic-related startup innovations in the middle of the 1970s the startup-innovation intensity of these industries and the remaining industries develop in an almost synchronized fashion up until the mid-1990s. Thereafter however, startup-firm innovation intensity in microelectronic-related industries significantly outpaces that of the remaining industries. This picture fits well with existing accounts of the development of startup activity in ICT-related fields.[670]

It has been stated in previous chapters that the literature suggests that both first-time innovators and experienced innovators are fundamental ingredients to the competitiveness and economic viability of industries and nations. The following section will probe these two ends (and all innovators found in between) of the innovator spectrum focusing on firms innovating in microelectronic-related industries.

7.4.2 Innovation persistence in microelectronic-related industries

The four microelectronic-related industries house some of the more frequent innovators in the SWINNO database. All except one of the top five most frequent innovators in these industries also appear in the top five on the aggregated list including all innovators.[671] Only Satt Control, a developer of control and operator systems, is new to the list.[672]

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[669] Bengtsson 2000

[670] Johansson 1999b p. 233f

[671] Table 6.7

[672] While the top four firms are all large (>10 000 employees) Satt Control is found to vary between size class eight (200-499 employees; size medium) and nine (500-999, size large) during the period. In 1994 Satt Control was acquired by Alfa Laval Automation and

Table 7.6 Top five innovators in microelectronic-related industries

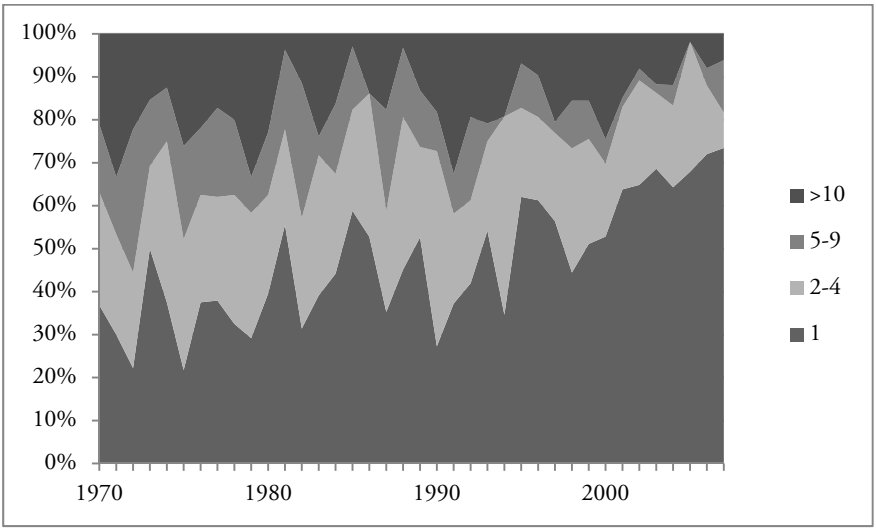
Place	Firm	Microelectronic-related innovations
1	Ericsson	85
2	ASEA/ABB	61
3	Saab	43
4	Volvo	13
5	Satt Control	11

Note: Aga, Alfa Laval, and Sony Ericsson Mobile Communications share sixth place with nine micro-electronic related innovations each.

The development of the top five innovators' share of total microelectronic-related innovation output is given by the uppermost field in figure 7.4. The share is subject to fluctuations but has a long-term downward trend. Moving downwards in the figure we arrive at the fields where firms are categorized into those innovating on more than ten occasions, on five to nine, on two to four, and those that have innovated on one single occasion.

continued activities under this name. The company was later (1999) purchased by ABB. There are hence no innovations from Satt Control in SWINNO dated later than 1994.

Figure 7.4 Innovations in microelectronic-related industries commercialized by firms innovating on one occasion, two to four, five to nine, and on more than ten occasions, 1970-2007 (percent)



The pattern reaffirms the conclusions drawn with regard to the development of startup-firm innovation in microelectronic-related industries; there is not much innovative entry during the 1970s and the 1980s, neither from startup firms nor, as seen here, from first-time innovators in general. The growing share of innovations from first-time innovators in the 2000s is a reflection of the increase in startup-firm innovation seen in the previous section. Firms innovating on five to nine occasions are more or less absent in the new millennium. All in all, it seems that innovation in microelectronic-related industries has evolved from being the produce of established firms to being that of first-time innovators and startups, but that this shift is relatively recent.

7.5 A closer inspection of innovations in microelectronic-related industries

The objective of this section is to provide an account of the development of innovation in each of the four microelectronic-related industries. For the evolution of the absolute number of innovations in these industries consult appendix E.

7.5.1 Office machinery and computers

Office machinery and computer innovation is the sole existing group of microelectronic-related innovations that stagnates (declines in relative terms) over the period.[673] Several different types of actors contributed to the creation and buildup of a Swedish computer industry. Among other prominent players there were the producers of mechanical office machinery (in the early days primarily Facit and Addo), there was the military (accelerating the procurement of cutting edge navigation and maneuvering technology, which engaged firms like Saab, Standard Radio och Telefon, Facit, and Bofors), and there was the public institution Matematikmaskinsnämnden, which in the early 1950s developed the mainframes BARK and BESK seeking to build Swedish competence in computers. The birth and adolescence of the computer industry took place within this complex of large firms, the military, and Matematikmaskinsnämnden.[674]

Accordingly, large firms and their spin offs dominate the SWINNO innovator scene in the 1970s. Key players include Stansaab, Asea, Datasaab, Ericsson, and Facit. A notable firm start in the 1970s was Mydata founded in 1973 by Lennart Stridsberg, which launched the two desktop computers My-15 and My-16. The only Swedish microcomputer that was ever produced on a large scale (ABC 80) was launched in 1978, by Luxor.

[673] Figure E.2 and table 7.2.

[674] See Eliasson (1998) for a comprehensive account of the development of the Swedish computer industry.

Initially, sales looked promising, but production subsequently came to a halt in 1986. It became obvious that Luxor had bet on the wrong horse when a company advertisement campaign posed the question "*Who needs to be IBM-compatible?*" Although there were occasional successes like the case just mentioned as well as Standard Radio och Telefon and Staansaab's computer screen system Alfaskop, Swedish firms never managed to achieve or sustain competitiveness in desktop computers, terminals, nor mainframes.

From 1975 onwards there is a remarkable decline of the share of large firm innovations in the computer industry.[675] The large firm segment falls from a period average of 60.5 percent in the period 1970-1975 to a period average of 11.4 percent in the period 1994-2007. The lost ground was gained by small firm innovations, between the same two periods small firms move from accounting for a mere 15.1 percent of the innovations to 78.8 percent. The computer industry experiences an increase in startup innovation from 1990 onwards and a growing share of the innovations coming from one-time-innovators. These developments aside, the industry witnesses the proportion of its new-to-the-world innovations decrease throughout the period: from 28.4 percent in the period 1970-1975 to 7.3 percent in the period 1994-2007. Similarly, the share of highly novel innovations from the perspective of the innovating firm is low in comparison to other industries. These findings indicate that the Swedish office machinery and computer industry is primarily (and increasingly) a technology taker rather than a supplier of ground-breaking technology.

The computer industry experiences a distinctive change in innovation and the characteristics thereof. From desktop computers and large systems developed by large firms in the 1970s and early 1980s to vehicle computers, printers, servers, high tech scanners, keyboards, computer mouse devices, and data pens developed primarily by small firms in the late 1980s, 1990s and 2000s. Taking the shift in innovator size, the changing character of innovations, and the increasing share of startup-firm innovation all into account what becomes clear is that the 1980s mark a period of profound intra industrial change, albeit in terms of technology at some distance from the absolute frontier. Nonetheless, the stagnant number and relative decline

[675] Table E.1

in innovations suggests that this industry is far from being the most dynamic of the industries represented in SWINNO.

7.5.2 Radio, television, and communication equipment

The assessment of leading Swedish firms' positions vis-à-vis foreign competitors during the 1970s (table A.1) suggests that radio, television, and communications equipment was a Swedish parade industry at the time. Swedish firms were ahead of foreign competitors in automatic circuits, telephone systems, and telephones. The modest contribution (figure 7.2 and table 7.2) and the low absolute number of innovations (figure E.3) during the 1970s all the way though the mid-1990s stand in sharp contrast to these positive assessments.

In the 1970s and 1980s innovations in the radio, television, and communication industry were commercialized by large firms to a larger extent than in any of the other three microelectronic-related industries; 75.8 percent of the innovations commercialized between 1970 and 1975 and 70.7 percent of those between 1975 and 1982 were to be large firm innovations.[676] The dominating innovators of the 1970s were Ericsson, Asea (primarily Asea Hafo), and Sonab. Each of the firms were active in different fields; Ericsson in telephone communications, Asea Hafo in semiconductors, and Sonab in audio technology. If observed over the entire period, Ericsson accounts for 24 percent of all the innovations in the industry. In no other industry does one single firm account for such a large share of total innovation output.

A distinctive feature of the Swedish telecom industry in the 1970s and 1980s was the close synergy between Ericsson and the public telecom agency Televerket.[677] The relationship was characterized both by procurement and joint development projects.[678] One example of the latter was Mobitex, a communication system designed for the transmission of both text and

[676] Table E.2

[677] To some extent, this relationship was described in chapter two, section 2.7.

[678] For the latter purpose Ericsson and Televerket founded the development company Ellemtel Utvecklings AB together.

speech developed in the early 1980s. This would ideally improve on the mono-directional Minicall system as Mobitex was a bidirectional system. The system was in still in use at time of writing, typically applied to directing traffic and was also adapted for ambulance and police car operations. Televerket was also the single developer of no less than six innovations (one in the 1970s and five in the 1980s). The innovations include telephone and radio communication systems.

Although Ericsson maintains the position as the top contributor of innovations, large firm dominance wanes in the 1980s to the strong emergence of small firm innovation.[679] The latter increase should be credited to existing small firms rather than startup firms. The rise in small firm innovations is correlated with an increase of innovations commercialized by one-time-innovators. Chapter two (section 2.7) reported a wave of entry into the telecommunication industry during the 1980s.

Even though the 1980s experience signs of renewal (e.g. an increasing share of small firm innovation) the industry's share of total innovation output is modest. Real takeoff in innovations by the industry does not take place until the mid-1990s. The period from 1994 to 2001 undergoes a surge of innovation. The increase (relative and absolute) is attributable first and foremost to innovations in the broad field of communication technology and is associated with the Swedish so called ICT "miracle".[680] This remarkable growth spurt can be traced to a revival in Ericsson and startup firm innovations. Ericsson innovated within fields where it was traditionally strong and in mobile communication, an area into which inroads were made in the early 1980s. The firm peaks in terms of the number of innovations commercialized in one year in 2000 with ten innovations. Innovative startup firms include Kreatel Communications (call router), Netcore i Lund (AC circuit for ATM and IP), Effnet (software-based router), Netcom Systems (broadband based on radio relay stations), and Wireless Solutions (mobile surveillance system which replaces field buses). Up until the last sub period there is an extreme polarization in the distribution of innovations across firm size. One can speculate whether this reflects a situation in which small

[679] Table E.2

[680] Edquist 2005

firms with growth potential become the prey of the large firms in the industry. The last sub period see the medium-size firm segment grow. Following the same line of reasoning, this may indicate increasing diversity.

The relative and absolute number of radio, television, and communication innovations collapses as the dot.com bubble bursts in the year 2000. The collapse is accompanied by a change in the innovator structure. The share of startup-firm innovations decrease and so does the general share of small firm innovation which drops from 61.1 percent in 1999 to 21.1 percent in 2000. Conversely, the large-firm share increases in the years immediately after the bursting of the dot.com bubble. The absolute and relative number of innovations, small firm innovations, and startup innovations all recover in the concluding five years of the period.

In conclusion, the radio, television, and communication equipment industry begin the period in a position where large firms are visibly dominant innovators. The situation changes in favor of small firm innovation during the 1980s although the contribution left by the industry to total innovation output during this decade was modest. The mid-1990s onwards is a period of intense activity. The absolute and relative number of innovations skyrocket and a considerable share of the innovations are commercialized by startup firms. The industry takes a severe blow from dot.com crash, especially in terms of the small firm innovation share, but recovers towards the end of the period.

7.5.3 Instruments

The instrument industry is the most stable of the microelectronic-related variety in terms of the number of innovations developed and share in total innovation output.[681] The dominant firms of the instrument industry are ASEA/ABB and Saab. The importance of ASEA/ABB‘s contribution to the industry's total innovation output is maintained throughout the period

[681] Figure 7.2, table 7.2, and figure E.4.

while innovations from Saab seize in the mid-1990s.[682] In comparison with the two hitherto discussed microelectronic-related industries, the small firm innovation share starts out from a stronger position accounting for 35.3 percent of the innovations between 1970 and 1975.[683] Nonetheless, the industry exhibits similarities with the other two in that the period 1982-1990 marks a shift from large firm to small firm innovation dominance. During the same period, startup innovations begin to increase from being almost non-existent in the 1970s. In the last sub period (1994-2007), another jump of small firm and startup innovation is apparent. Note however, that the number of instrument innovations and their share of total innovation output do not increase during this period.

21 percent of all academic-spinoff innovations in SWINNO are found in this industry. The instruments sector is thus the industry with closest links to academic research. Table 7.7 displays the element of academic-spin off innovations in the output of the industry throughout the period.

Table 7.7 Share of academic-spin off innovations in total instrument innovation output, 1970-2007 (percent, period averages)

	Academic-spin off innovations
1970-1975	6.3
1975-1982	5.7
1982-1990	10.7
1990-1994	11.3
1994-2007	17.9
1970-2007	11.8

Prior to 1994 67 percent of academic spin-off innovations in the instrument industry were commercialized by established firms compared to 33 percent by startup firms. In the final sub period (1994-2007), 74 percent of those spin-offs were commercialized by startup firms. Startup innovations based

[682] The absence of SAAB innovations in the second half of the 1990s and the 2000s is surprising. A potential explanation is that Saab is not explicit about innovations that go into defense equipment.

[683] Table E.3

on academic research during the last sub period include different kinds of sensors (developed e.g. by Alfasensor, Samba Sensors, SiTek Laboratories, AppliedSensor, and Vasasensor), measuring devices (developed e.g. by Paperprobe Sweden, Dynalyse, D-Flow, Proximon Fiber Optics, Pax Diagnostics, Rotfinder, and Soliton Elektronik), and medical instruments (developed e.g. by Aerocrine, Scibase, and C-Rad).

The instrument industry produces a stable number of innovations and leaves an equally consistent contribution to total innovation output throughout the period. Similar to the categories of office machinery and computers and radio, television, and communications industries, the instrument industry sees small firm innovation become increasingly important from the 1980s onwards.[684] The industry markedly increases its share of startup-firm innovation after the 1990s crisis. Given the sustained high share and absolute number of instrument innovations, the extensive entry of new innovative firms, and the frequent academic-spin off innovations this industry must be considered as one of the more dynamic in the Swedish manufacturing sector during this period. However, just like office machinery and computers, it represents the category of microelectronic *adopters* rather than suppliers.

7.5.4 Software

Software ('Computer and related services', SNI 72) is dependent like no other industry upon the development of computers and microelectronics. With regard to software innovations in SWINNO, the industry had a slow start.[685] There are only four observations of software innovations in the 1970s. Coding difficulties may explain this particularly low number. These difficulties stem from the fact that early on software was embodied in other products, such as for example industrial process control equipment (SNI 33.3). Regrettably, the software and instrument innovation count of the 1970s and 1980s may therefore be flawed. The coding difficulties subsided as software become products in their own right and articles in the journals

[684] Table E.3

[685] Figure E.5

became clearer regarding the character of the innovations by adopting a language more similar to that of the constructors of the SWINNO database.

Software innovations display two periods of notable increase (both in relative and absolute terms). The increases take place during the 1980s and from 1994 until the conclusion of the period.[686] Of the two increases the former is merely a foretaste of the development seen in the later period. Software innovations nearly vanish from total innovation output during the crisis years of the early 1990s. Once the crisis had settled the industry experiences a true innovation surge.[687] By the end of the period the industry is abreast with "big" innovation industries like those of machinery and equipment and instruments. Intriguingly, the software innovation series shows no significant downward trend in response to the dot.com crash unlike the radio, television, and communication equipment industry.

Small firms account for approximately 60 percent of all software innovations.[688] Additionally, 83 percent of the innovations are commercialized by one-time-innovators. This high percentage makes the industry the most experiment intense of all industries. Startup innovation in software however is a phenomenon primarily restricted to the last sub period during which it grows increasingly important. This finding resonates the received view.[689] While in the period 1982-1994 only 14 percent of the instrument innovations originate in startup firms, in the period 1994-2007 this number is 38 percent.

To conclude, similar to radio, television, and communication innovations, software innovations grows increasingly important in the second half of the 1990s. But, *unlike* in the former, the number and share of software innovations do not suffer a severe blow by the dot.com crash. Small firms, including startups, are of fundamental importance to innovation in this industry.

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[686] Figure 7.2 and E.5.

[687] Table 7.2

[688] Table E.4

[689] Johansson 2004

7.6 On the negative side of transformation

A central tenet of the theoretical framework developed by Erik Dahmén is that there is always a positive and a negative side to industrial transformation; there are both winners and losers. Section 7.5 explored the development of innovation in industries on the positive side of transformation. Those industries were all closely linked to the dynamic development of microelectronics.

The slowdown of the world economy in the 1970s, increased competition, and falling demand put some of the Swedish parade industries under a relentless pressure to transform. Transformation pressure may produce a variety of responses. Firms may invest in the opportunities offered by the positive side of transformation, which in this case would concern the incorporation of microelectronics in particular. One illustrative example of a firm that opted for this strategy is ASSA, a producer of lock systems, which integrated the new technology into its products and commercialized its first microcomputer-based lock system in 1981. The chosen trajectory proved to be successful; in 2006 ASSA commercialized a high-tech lock system based on CAN-technology and had established itself as a world-leading producer of intelligent lock systems.[690]

Another method of tackling transformation pressure is through product diversification or alternatively through a total reorientation of production. The latter was discussed in investigations relating to the future of the shipbuilding industry in the south western part of Sweden in the late 1970s.[691] Alternatively, responding to transformation pressure could involve sticking with the chosen strategy and waiting for demand to increase again. As was seen in chapter two, this strategy was the one opted for by the political establishment when faced with the international downturn in the early 1970s. According to the dynamic capability literature addressed in the introductory chapter, this strategy is rarely successful in the long term.

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[690] CAN stands for Controller Area Network.

[691] Varvet och Vi 1978 p. 3

More than other industries, shipbuilding, iron and steel as sectors are associated with the slowdown of the 1970s. The magnitude of the crisis is indicated by the fact that large parts of both industries were subject to nationalization in the second half of the 1970s. Shipbuilding innovations are part of the 'Other transport equipment' category (SNI 35). A separation of shipbuilding innovations from the aggregate SNI category leaves a remainder of 44 shipbuilding innovations. That amounts to around one percent of the total amount of innovation output. The 72 iron and steel innovations found in the 'Basic metals' category (SNI 27) account for 1.8 percent of total innovation output. Evidently, in comparison with the innovations in the four microelectronic-related industries discussed above, the contribution made by these two industries is miniscule. The character of shipbuilding and iron and steel innovations in these two industries will be explored. Thanks to the relatively low amount of observations, it is possible to base these investigations upon the descriptions of the innovations.

The development of machinery and equipment innovation will also be analyzed. This is important not least because the industry is of fundamental importance to the Swedish economy. The well-established capital goods producing industry suffered as investments fell in parallel with the international slowdown and the protracted structural crisis in the second half of the 1970s and the first years of the 1980s. If low demand exerted a negative transformation pressure, the potential opportunities offered by microelectronics exerted a positive pressure to transform. Section 7.6.3 investigates the slowdown of the industry that dominated total innovation output initially but saw both its share of the total amount of output and the number of its innovations drops significantly in the beginning of the 1980s. Given the large number of innovations (n=1175) the investigation of machinery and equipment innovations is less qualitative than that of shipbuilding and iron and steel innovations.

7.6.1 Shipbuilding

Swedish shipbuilding in the mid-1970s was highly specialized in serial production of oil tankers and cargo ships.[692] Increased international competition together with decreasing demand for these ship categories put Swedish ship builders in a precarious situation. Subsidies and government ownership aimed to buoy the crisis-hit shipyards. Svenska Varv closed several of the large yards to reduce excess capacity. None of the remaining ones continued the production of cargo ships in the long run. Götaverken-Arendal made inroads into the offshore industry, Finnboda and Cityvarvet specialized in repairs, and Karlskrona and Kockums focused on the production of naval vessels.[693] In 1985 production subsidies seized. This embodied the death knell to Uddevallavarvet to mention but one example.[694] Svenska Varv was renamed Celsius in 1987. The aim of this "new" firm was to transform the remnants of the shipyards into diversified engineering and contractor firms.[695] Karlskrona and Kockums joined forces in 1989 to continue specialization in naval vessels and submarines and are still competitive in these areas at time of writing. The character of shipbuilding innovations shall now be set against the background previously outlined.

Three fourths of the shipbuilding innovations emerged before 1987 and one fourth after 1990. Of the (in total) 44 innovations, 15 were commissioned by the military. Another four were clearly aimed at military purposes although it was not stated in the articles that they were cases of public procurement. The majority of these innovations were developed by either Karlskrona or Kockums. These innovations include the stealth corvette Visby and several mine sweepers. Sutec and Saab were likewise engaged in the development of military marine technology.

Kockums discontinued its production of cargo ships in 1987. Prior to doing so the firm accounts for two such related innovations in the database: a roll

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[692] Gawell and Pousette 1985 p. 197

[693] Ibid.

[694] Elsässer 1992 p. 300

[695] Ibid.

on/roll off ship in 1980 and a container vessel with an advanced loading system in 1984. RoRo technology and the development of a system that rationalizes loading are both signs of a strategy to develop cutting edge ships while remaining within the domain of freight vessels. Similarly, Uddevallavarvet launched Nanny, a supertanker loading 499 000 deadweight tons. When she headed out from Byfjorden in 1978, Nanny was the largest tanker in the world. The only distinguishably reoriention type innovations originate from Götaverken as the firm diversifies into the offshore industry. During the late 1970s and early 1980s Götaverken launches an offshore living platform, a multi-purpose support vessel for offshore operations, and both a semi-submersible and a high-tech oil rig. In addition to the offshore enterprise the firm launches a high-tech carrier for chilled goods in 1979, a life boat in 1983, and a new icebreaker in 1987. Hence, of the large shipyards only Götaverken tries to break into distinctly new markets.

As regards actors other than the large well-known shipyards, one notable contributor to the industry's innovation output is Marinteknik Verkstads which launches three high-tech catamarans in the period. Compared to the situation in other industries, startup-firm innovation is almost totally absent in the shipbuilding industry. This is not very surprising. High capital intensity likewise gives high barriers to entry.

7.6.2 Iron and steel

The iron and steel industry is part of the aggregate 'Basic metals' category (SNI 27).[696] Chapter two noted that the iron and steel industry in Sweden benefitted greatly from the seemingly insatiable demand from reconstructing European countries in the decades following the Second World War. Swedish production of iron and steel products grew fivefold from the end of the war until 1970.[697] Forecasts in the first half of the 1970s were optimistic

[696] See table 7.1. There are five three digit sub categories to 27 in SNI 2002; 'Iron and steel mills' (27.1), 'Iron and steel tubes' (27.2), 'Other first processing of iron and steel' (27.3), 'Basic precious and non-ferrous metals' (27.4), and 'Metal foundries' (27.5). Of these the three first are considered to constitute the iron and steel industries.

[697] Ruist 1985 p. 163

and production capacity was increased accordingly.[698] Swedish steel production peaked in 1974 to six million tons of crude steel and four million tons of special steel.[699] In addition to international demand, the industry had a major destination market in the domestic shipbuilding industry and the so-called "million program" which was a public housing program. When both the international and the domestic market cooled the iron- and steel mills found themselves with a lot of excess capacity. Slack and standstill were detrimental to the capital intensive mills. A period of rationalization and restructuring of the entire industry ensued. The major producers of crude steel (Domnarvet, Norrbottens Järnverk, and Oxelösund) were placed under government ownership (Svenskt Stål AB). The restructuring plan prescribed that Domnarvet was to specialize in steel bands and sheets, Oxelösund in industrial plate with much value added, and Norrbotten in crude and semi crude profiles.[700] Likewise, the alloy steel industry experienced the development of far reaching product specialization among producers. Avesta came to specialize in stainless steel sheets, bands, and welded pipes, Sandvik in wire and seamless, stainless tubing, SKF Steel in structural alloy and bearing steel, Uddeholm Tooling in tool steel and stainless bars, and Kloster Speedsteel in speed steel.[701] The common features and results of this restructuration surge was an increase in value added to the steel products and intensified specialization thereof.[702] The specialization was conducive to mergers, acquisitions, and increased foreign ownership throughout the period.[703] This brief background account raises some expectations with regard to innovation output. Specialization in niches could be expected to lead to an increasing number of innovations each characterized by a significant amount of value added.

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[698] Ibid.

[699] Jonsson 2011 p. 173

[700] Jonsson 2011 p. 174-5

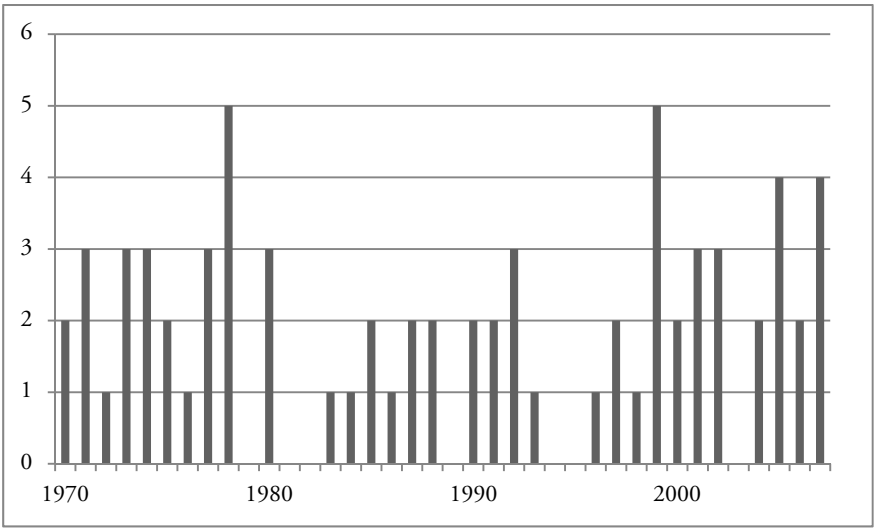
[701] Ruist 1985 p. 166. SKF Steel merged with the Finnish firm Ovako in 1986. Together they formed Ovako Steel. The firm was discontinued in 1991 as the Finnish and Swedish parts went separate ways (Ruist 1992 p. 262).

[702] Abrahamsson and Ruist 2011 p. 175-6

[703] Ibid.

72 innovations are found in the iron and steel industry, all of which are distributed as shown in figure 7.5. Although the total number of innovations considered is low, figure 7.5 illustrates two periods during which a higher number of innovations commercialized annually is sustained; the 1970s and the 2000s. 32 percent of all steel innovations were commercialized during the very first decade of the period while only 17 percent of them were commercialized in the 1980s, a decade characterized by downsizing and restructuring. The SWINNO data therefore seems thus to suggest that while the 1980s may have been a period of far reaching reorganization and reorientation of production, few groundbreaking innovations were commercialized. The recovery of innovation output in the 1990s and the 2000s would, according to the brief background given above, be expected to consist of a higher density of niched innovations in contrast to those of the 1970s.

Figure 7.5 Iron and steel innovations, 1970-2007 (n)



An absolute majority of significant metallurgical process innovations found in the database occur during the 1970s. The processes aim both at cutting costs and improving the quality of steel. Cutting edge processes are launched by Uddeholm (e.g. the CLU process which replaces the expensive argon gas with oxygen plus steam and the water granulation Granshot process), Stora (the powder metallurgic Asea-Stora process and the pig iron Rotovert

process), Boliden (the pig iron INRED process), and Gränges (the Gränges-Nyby process for the production of seamless, stainless pipes). In addition to these metallurgic processes, in the 1970s different types of industrial plate come to the fore (e.g. plastic laminated sheets) for which Norrbottens Järnverk was chiefly responsible. Special steel innovations account for only a minor share of the innovations. The most frequent innovators of the decade are Uddeholm, Stora (owner of Domnarvet) and Norrbottens Järnverk.

The composition of innovation output changes in favor of alloy steel innovation during the 1980s and 1990s. Moreover, innovations are distributed among a larger number of firms. The relatively low number of innovations (especially when compared with its performance in the 2000s) launched by SSAB (Svenskt Stål AB) is notable given its otherwise dominant position. Its relative absence of innovations in SWINNO seems to suggest that the firm was concentrating on establishing itself rather than innovating during the 1980s and 1990s.

In the 2000s there is an indisputable dominance of advanced special steel qualities in innovation output. The years of the new millennium see SSAB dominating the innovation scene with associated high tech steel families such as Hardox, Toolox, and Docol. Another prominent innovator is the tool steel producer Sandvik. The changing character of these innovations seems to meet the expectations that were raised in the brief background account provided at the beginning of this section; Swedish steel producers moved in to high tech niches. However, the change was slow; not until the new millennium does innovation output reach the level seen in the 1970s.

7.6.3 Machinery and equipment

This category is singularly the most diverse of the manufacturing industries. It houses products as varied as bandwagons and calenders (although both flatten what has been run over). Together, the different sub groups form one of the more important driving forces behind the strong Swedish performance in the decades following upon the end of the Second World War.[704] However, towards the close of the 1960s both the relative increase

[704] Schön 2000 p. 422. See table E.5 for the different subgroups.

and the industry's share of value added in the manufacturing sector stagnated.[705] By 1975 production volumes decreased.[706] Relatively short lead times in the production of capital goods made the machinery and equipment industry highly sensitive and vulnerably exposed to investment activity changes. The industry had thus to deal with the hefty swings of the business cycle in the late 1960s, the 1970s, and the first half of the 1980s.[707] Production of machinery and equipment recovered in the second half of the 1980s, slumped during the early 1990s crisis and picked up again thereafter.[708]

The industry went through thorough structural change during the 1970s and 1980s.[709] The most notable shift observed during the 1970s was the advancement and rise of the general and special purpose machinery sector, especially surrounding lifting apparatus and processing machinery and equipment.[710] In the latter category wood processing machinery experienced particularly fast growth.[711] During the 1980s, the processing machinery sector became more important to the industry, while the particularly positive development observed in wood processing machinery reversed in the second half of the 1980s.[712] Forest machinery and machine tools are also found on the decline side during the 1980s. The same decades evidently exhibit increasing investments in R&D, especially among the large firms, who dominate the industry at this juncture.[713] In 1989 around ten percent of the value added was invested in R&D, two percent higher than the manufacturing sector average.[714] The magnitude of this R&D surge can be

[705] Jagrén 1985 p. 175

[706] Figure E.6

[707] Figure E.7

[708] Figure E.6

[709] Lindqvist 1992 p. 276-277

[710] Jagrén 1985 p. 177

[711] Ibid.

[712] Lindqvist 1992 p. 277

[713] Jagrén 1985 p. 181, 186; Lindqvist 1992 p. 277-8

[714] Lindqvist 1992 p. 278

gathered when considering that only four percent of the value added is invested in R&D in 1971 compared with 14 percent in 1987.[715] 85 percent of the R&D undertaken is related to the development of new products.[716] The intensification of R&D efforts was further augmented by the adoption of CNC, CAD/CAM, and FMS systems all of which enabled faster development, design, and construction of new products.[717]

The machinery and equipment industry is rich in accumulated knowledge in mechanics, hydraulics and pneumatics. The majority of innovations during the 1970s and 1980s are based upon one or more of these basic physical principles. The major change in the physical character of machinery and equipment innovations during the period studied in this thesis surrounds the increasing use of microelectronic components.[718] However, explicit mentioning of "microelectronics" during the 1970s is sporadic at best. When microelectronics appears in lifting/handling and general purpose machinery innovations, it is primarily in different types of scales (chiefly weighbridges), processing machinery, robots, and transporters. ASEA was the cutting edge developer of microelectronics-based robots. IRB 6; a general purpose robot with five degrees of freedom commercialized in 1973, was for example the world's first robot entirely based on microelectronics. In the 1980s microelectronics begin to complement mechanics, hydraulics, and pneumatics in a wide spectrum of products; from filtering equipment to forestry and agricultural machinery. Microelectronics become a more implicit product characteristic as the period passes. As "microelectronics-based" ceases to be a unique selling point and becomes to a large degree taken for granted, the explicit mentioning of the term in the articles wanes.

Large firms in the machinery and equipment sector has more than any other pioneered the increased sales of product systems and related services discussed in chapter five and six.[719] For instance, as early as the 1960s Alfa-

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[715] Ibid.

[716] Jagren 1985 p. 181

[717] Jagrén 1985 p. 182-3; Lindqvist 1992 p. 278, 280. CNC stands for Computer Numerical Control, CAD/CAM for Computer Aided Design and Manufacturing respectively, and FMS for Flexible Manufacturing System.

[718] Jagrén 1985 p. 185

[719] Jagrén 1985 p. 184-5; Davies 2004; Berggren et al. 2005

Laval pioneered the equipping of entire dairies, Tetra Pak built multi operation beverage packaging systems, and Gunnebo Bruk offered surveillance systems including fencing, TV cameras etc.

The trends described in brief above are likely to be reflected in the output of machinery and equipment innovation. In addition to changes in the composition of products a greater degree of microelectronics in the innovations is expected. On another note, the growing importance of system and service sales is a potential explanation of the decreasing number and share of innovations in the industry; generic innovations decrease to the benefit of customized and tailored solutions developed for a particular customer.

The majority of machinery and equipment innovations are found in the sub categories 'Machinery for the production and use of mechanical power, except aircraft, vehicle, and cycle engines' (SNI 29.1), 'Other general purpose machinery' (SNI 29.2), 'Machine tools' (SNI 29.4), and 'Various other special purpose machinery' (SNI 29.5).[720] Innovations in the first sub category include boat engines, gas and water turbines, compressors, valves, ball bearings, hydraulic power transmission equipment etc. 'Other general purpose machinery' encompass for example scales, filtering, separation, and purification apparatus, packaging machinery, gas generators, centrifuges, and vending machines. 'Machine tools' include powered hand tools as well as tools for the processing of metal, wood, rubber, glass, stone etc. 'Various other special purpose machinery' as a category houses all conceivable appliances that cannot be found in any other category. Examples include dehumidifiers, printing presses, garbage grinders and electrical boilers. In addition, all industrial robots with a wide spectrum of use are found in this category. Robots used for lifting, loading, and manufacturing are found in 'Machinery for the production and use of mechanical power (with the exception of the aircraft, vehicle, and cycle engines)' sub category.

General and special purpose machinery is by far the most prolific of sub groups in terms of innovation.[721] More than the other sub groups these two groups taken together are responsible for the large number of innovations

[720] Table E.5

[721] Table E.5

during the 19070s and the first half of the 1980s.[722] This finding supports the received picture reproduced in the beginning of this section. General purpose machinery elevated the quantity of innovations in the 1970s while special purpose machinery sustained the high number into the 1980s. Innovations in both categories fall back during the 1980s and the absolute and relative decrease in machinery and equipment innovations can thus be explained to a large extent by a decrease in innovations within these two sub groups. This finding should be set against the background of strong growth in R&D, in particular geared towards the development of products, in the 1980s.

Large firms dominate the innovation output of these two subgroups in the period 1970-1975. However, in contrast to 'Office machinery and computers' and 'Radio, television, and communication' the dominance is not as absolute.[723] There is a differential of only six percent between the share of small firm and large firm innovation in the volume of general purpose machinery innovation output in the period 1970-1975 (the largest of the sub groups).[724] Within the two sub groups, small firm innovation plays an increasingly important role during the period but it does not reach the levels attained in office machinery and computers, instruments, and software. However, the small firm innovation element in general and purpose machinery innovation output is larger than that in radio, television, and communication equipment innovation output during the last sub period (1994-2007).[725]

The intensification of startup firm innovation output seen in office machinery and computers, radio, television, and communication equipment, instruments, and software is also observed in the two largest machinery and equipment sub groups. However, the startup-firm innovation share is more modest. While between 1994 and 2007 startup firms account for 28 percent of office machinery and computer innovations, 20 percent of radio, television, and communication innovations, 27 percent

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[722] Figure E.8 and table E.6.

[723] Compare tables E.1 and E.2 to tables E.7 and E.8.

[724] Table E.7

[725] Compare tables E.2, E.7, and E.8.

of instrument innovations, and 38 percent of software innovations, a mere 12 percent of general purpose machinery innovations and 19 percent of special purpose machinery innovations originate in startup firms.

The main finding in relation to the structure of machinery and equipment innovation output is that the relative and absolute decline is attributable to the two sub groups of general and special purpose machinery. It was found that a growing share of the innovations is commercialized by small firms but the portion of startup innovation is modest. The absolute and relative decline of the industry in the 1980s combined with the growing importance of small-firm innovation together stand in sharp contrast to the increase in R&D spending, particularly by large firms, during the decade. It seems as if these investments did not pay off in terms of the nature of innovations studied in this thesis. The literature notes that large firms increasingly engage in system innovation and customization of innovations during the period, the extent of which can be arrived at only through guesswork given the data at hand. Judging from the absolute and relative decrease in machinery and equipment innovations, it is apparent that small and medium sized innovators do not fill the gap left by the large firm innovators as they either engage in other types of innovations or indeed become less innovative.

7.7 Triangulation

This chapter addressed research question number three: *Was there an observable key period of change in structural composition of innovation output and if so, when did it take place*? by exploring changes in the structural composition of innovation output. Output evolved from being dominated by capital goods (i.e. machinery and equipment) to being largely produced by radio, television, and communication equipment, instruments, and software. These industries, together with the office machinery and computer industry were argued to be more closely related to microelectronics than the remaining industries. The chapter investigated both the innovators and the characteristics of innovation in these microelectronic-related industries, provided further elaboration on the subject and brief background accounts to developments in the area. In the final section the chapter examined those innovations in industries whose share of total innovation output declined

and who were negatively affected by the structural crisis in the late 1970s and the 1980s.

The structural composition of innovation output was found to change in the style of a two-stage takeoff process. The first wave of change appeared in the 1980s and a second in the 1990s. Figure 7.2 and table 7.2 showed that instrument innovations, and to a lesser extent software began to increase in the first wave of change while machinery and equipment innovations fell back in this regard. The second wave of change was largely driven by radio, television, communication equipment and software innovations. Innovations in the first category include modems, routers, broadband, and Bluetooth-based innovations, as well as cell phones. With few exceptions, innovations found in this category are targeted at increasing connectivity through communication infrastructures. Software innovations presuppose the existence of hardware infrastructure and increase the value thereof by providing associated services.

These basic findings should be included center frame against the traditionally received accounts of structural change in the manufacturing sector as they were reviewed in chapter three. As with regard to the previous two research questions, Swedish growth school and structural analytical narratives differ when it comes to the dating of the key period of structural change in the manufacturing sector. Swedish growth school accounts argue that the 1980s indeed experiences some signs of transformation but the decade is otherwise described as being characterized by structural lock-in. The Swedish growth school is particularly skeptical about the extent to which firms in crisis-hit industries underwent renewal and to which there was sufficient entry into new areas. Crisis policy is argued to have sanctioned established structures. The 1990s is argued to have seen the transformation tempo increase and the decade is considered as the one during which new structures take hold, chiefly represented by the momentum gained by the ICT industry.

The structural analytical narrative on the other hand, describes the 1980s as a decade of profound reorientation including both restructuring of firms in crisis-hit industries and widespread investments in business opportunities based on new technology with much economic potential. The second half of the 1990s saw new structures mature and culminate and accordingly, investments increasingly came to regard efficiency rather than significant innovation.

It was stated in chapter three that the major difference between the two research traditions pertains to whether the development during the 1980s delayed or enabled the strong growth of the second half of the 1990s and the new millennium. Whereas the Swedish growth school ascribes to the former position, the structural analytical perspective poses that the restructuring of the 1980s was sufficient to lever the positive development of the 1990s. We are thus left with the issue of whether the 1980s saw *satisfactory* restructuring. The finding that there was a wave of change in the structural composition of innovation output in both the 1980s and 1990s suggests some support to both research traditions.

The structural analytical perspective suggests that 'transformation' and 'rationalization' periods see innovations of different character. Transformation periods are the eras of groundbreaking developments in physical products of generic character whereas rationalization periods witness incremental innovations and other types drawing on, or enabled by, generic products developed in the preceding 'transformation' period. The finding that the first wave of change in the structural composition of innovation output took place in the 1980s suggests support to the structural analytical narrative. There are few of the small constituents of the microelectronic revolution to be found in SWINNO; the number of microelectronic component innovations is negligible.[726] This lack of supply thereof together with the increasing use of such components (in e.g. instrument, machinery and equipment innovations) suggests that with regard to such products, Sweden was a technology taker. The character of the innovations behind the second wave of change in the structural composition of innovation output fits with the anticipated shift in the character of innovations. Telecom and software innovations draw on an infrastructure enabled by developments in microelectronics and add value thereto. The increase of such innovations can be argued to be in line with the structural analytical model.

With regard to the size of firms commercializing microelectronic-related innovations, it was discovered that there exists a more pronounced dominance of small firms in these industries in comparison to the remaining

[726] Such innovations are found in the Radio, television, and communication equipment subgroup Electronic valves and tubes and other electronic components (SNI 32 100).

industries in the SWINNO data. In the final sub period (1994-2007), small firms accounted for nearly 70 percent of the innovations in microelectronic-related industries, whereas in contrast they accounted for only 53 percent in the remaining industries.[727] The major increase of small firm innovation takes place between the first half of the 1970s and the 1980s as the share of such innovation in total innovation output goes from 30.4 percent in the former period to a portion of 59 in the latter. Startup innovation intensification in these industries is largely restricted to the last sub period (1994-2007).

The firm size pattern lends some support to both research traditions. The strong increase of small firm innovation in the 1980s fit with the period generalization suggested by the structural analytical perspective. The stylized explanatory model underlying this perspective suggests that 'transformation periods' are characterized by firms (a considerable part of which can be expected to be new and small) rushing in to create and seize business opportunities based on new technologies. However, the stylized view of 'rationalization periods' does not reflect the continued increase of small firm innovation into the new millennium. This view would suggest 'rationalization' intervals to be characterized by intensified competition and the shake-out of unprofitable or otherwise unviable firms rather than the gaining of ground by new and small firms. However, whereas these stylized elements can be read into the explanatory model the structural analytical *narrative* recognizes that structures such as the industrial firm population co-evolve with technology and management practices. According to the narrative, such new structures culminate and mature in the second half of the 1990s. A breakdown of microelectronic-related startup innovations into the four constituent industries suggests that a large share of such innovations in the 1990s and 2000s were by their nature service or connectivity-related innovations which are, as was already pointed out, alleged to characterize 'rationalization' periods.[728]

The strong growth of startup-firm innovation in microelectronic-related industries during the last sub period (1994-2007) lends support to Swedish

[727] Tables 7.3 and 7.4.

[728] In addition to telecom and software innovation, instrument startup-innovations appear to increase during the 1990s and 2000s.

growth school narratives. The entrepreneurial climate is suggested to have improved significantly after the 1990s crisis and consequently, a sizeable increase of innovative entry is to be expected only in the aftermath. These narratives stress the following as critical factors: increased access to and supply of venture capital, the reformation of the tax system in 1990/1991, and other institutional reforms that changed incentives and regulations surrounding firms.[729]

The surge of microelectronic-related startup innovation in the 1990s and 2000s may thus be interpreted as being enabled by a combination of changed institutions, a burgeoning venture capital market, new firm structures, and business opportunities exposed by the culmination and maturation of development blocks centered on ICT. Such an interpretation of startup-firm innovation in microelectronic-related industries found in the SWINNO data draws upon both the Swedish growth school and the structural analytical perspectives.

One point on which there is fundamental disagreement between the Swedish growth school and the structural analytical narratives concerns the extent to which industries on the negative side of transformation underwent rapid and sufficient restructuring during the 1980s. The Swedish growth school argues that misplaced subsidies and poor monetary policy caused lock-in whereas the structural analytical perspective in contrast claims that firms in crisis-hit industries restructured rapidly and in profound ways. Sections 7.6.1 through 7.6.3 explored innovations in the shipbuilding, iron, steel, and machinery and equipment industries respectively. Whereas firms can restructure by alternative means other than through product innovation the character of the innovations developed during the structural crisis may provide a hint about the crisis strategies adopted by these industries.

The majority of the large Swedish shipyards seem to have continued to concentrate resources on tankers and cargo ships well into the 1980s. However, these ships were equipped with significant amounts of advanced technology. Only Götaverken focused on related product diversification as the firm broke into the offshore industry. The iron and steel industry was

[729] An increase in the capital under management by venture capital firms as percentage of GDP from the mid-1990s onwards is reported by Lerner and Tåg (2013).

responsible for remarkably few innovations in the 1980s (and in the 1990s). While on the one hand a profound organizational restructuring of the industry was under way where the majority of the large mills were moving into niches, on the other hand there were no immediate results in terms of groundbreaking product innovations. However, of the few innovations commercialized during the decade, an increasing number comprise alloy steel rather than crude steel products. There is a notable absence of SSAB, the major Swedish steel player among the steel innovators of the 1980s. This firm seems to have been engaged in restructuring by alternative means rather than through product innovation. All in all, the explorations of the number and characteristics of innovations commercialized in the, to a considerable extent subsidized and nationalized, shipbuilding and iron and steel industries during the second half of the 1970s and during the 1980s do not display any far reaching reorientation strategy in terms of innovation. The inertia suggested by the Swedish growth school can thus not be rejected on the basis of findings.

The machinery and equipment industry experienced serious challenges during the structural crisis though firms in this industry were never subject to subsidies or government takeover. While the structural analytical perspective suggests that the industry managed to catch the wave of transformation the Swedish growth school suggests that specialization in knowledge-intensive production was reversed during the second half of the 1980s.

In the total SWINNO innovation output, the machinery and equipment industry moves from being the dominating one to being placed on par with radio, television, and communication equipment, instruments, and software by the end of the period. The major decline occurred during the 1980s. The exploration of innovations in this industry engaged in an analysis of changes in the five-digit composition of the innovations. It was found that the fallback of machinery and equipment innovations could be attributed to a lower number of general and special machinery innovations. Machine tools, on the other hand, became relatively more important. With regard to the size of the innovating firms, it was shown that small firm innovation dominated from the late 1970s onwards. This finding is unexpected given the extensive R&D expenditures made by large firms during this decade. One potential explanation to the decreasing number of innovations in machinery and equipment and the contemporaneous fall back of large firm innovation in the industry could be the increasing importance of systems

and service innovation reported in the literature. Other possible explanations have been discussed in chapters five and six and include the possibilities that R&D expenditures meet with diminishing returns and that they regard costs of staying up to date with the international knowledge frontier.

The surge of machinery and equipment innovations around the end of the decade 1970 and the decline thereof from midways into the 1980s is primarily suggesting support to the Swedish growth school. From the structural analytical perspective, the fallback of innovation in the second half of the 1980s is not according to expectations. Rather, this model would suggest R&D expenditures in the large machinery and equipment industry to have paid of all throughout the so called 'transformation period' (the 1980s).

The next chapter will conclude by summarizing and discussing the main results of the thesis and highlight some potential directions for future research.

8. Conclusions and discussion

The stated aim of this thesis was to explore whether changes in the quantity and character of innovation output during the last three decades of the 20th century and seven years into the new millennium were associated with extended periods of relative prosperity and decline and to analyze and discuss any such association against the backdrop of received accounts of structural transformation. The temporal pattern of innovation (chapter five), the size of the innovating firms (chapter six), and the distribution of innovations across different industries (chapter seven) were investigated in turn.

The case explored in the thesis was the Swedish manufacturing sector. Long-standing international interest in Swedish economic policy and growth performance make it a relevant and interesting case study. This is particularly important as both Swedish and foreign academics have arrived at distinctly different conclusions with regard to the association between structural change in the Swedish manufacturing sector and the long-term growth performance of the country. These different interpretations motivated a prizing open of the "black box" of Swedish manufacturing innovations. Hence, a new database containing observations of nearly 4000 innovations commercialized in the period 1970-2007 was compiled with the ambition to investigate industrial transformation at the micro level.

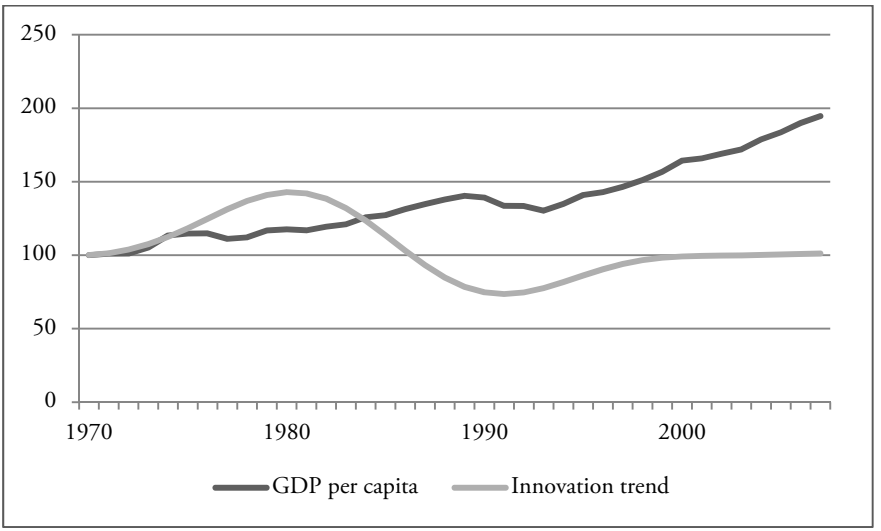
This concluding chapter is structured as follows: section 8.1 through 8.3 report the key results of the study. Section 8.4 undertakes a synthesizing analytical triangulation of the subject matter of this thesis by discussing its results from the point of view of the Swedish growth school and the structural analytical perspective respectively. Section 8.5 makes some concluding remarks and section 8.6 closes the thesis by highlighting some potential directions for future research.

8.1 The innovative 1980s

Technical change and innovation play a central role in formal growth models as well as economic historical accounts of economic growth and development. Whereas the mainstream neoclassical endogenous growth models suggest continuous innovation, where all innovations are of equal importance, evolutionary theories of economic growth suggest that innovation varies in frequency and character. The literature review in chapter one showed that this difference cuts through macro, industry, and micro level theories. Those assuming discontinuous innovation can be further divided according to their view of when in relation to performance (ranging from macro to micro) significant innovations appear.

This thesis found that the number of innovations varies widely and that the most innovation-dense period occurs as the Swedish economy is relatively stagnant and considerable parts of the manufacturing sector are going through hardship on account of falling demand and rising costs. In comparison to the innovation output peak in the approximate period 1975-1984, innovation output is meager during the 1990s and 2000s.

Figure 8.1 Innovation trend (n) and GDP per capita (constant prices) 1970=100, 1970-2007



Note: The wavelet transformation was performed by Fredrik N G Andersson. Source: GDP per capita: Schön and Krantz 2012.

Moreover, not only did we see more innovations being born in the late 1970s and early 1980s, but these innovations are also more significant than those commercialized in later decades. The categories of 'world market novelty' and 'novelty from the perspective of the product portfolio of the innovating firm' were both used as proxies for significance. The high level of novelty of innovations is sustained throughout the 1980s. Hence, with regard to uniqueness, technological leaps, and strategic reorientations, the 1980s seem to be the key period of innovation. The highly novel innovations were primarily products of existing firms. This pattern suggests that Swedish firms did not rest on their laurels during the economically stagnant period running from approximately the mid-1970s until the first years of the 1980s. Rather, they were engaged in far reaching restructuring through innovation. These finding provide empirical resonance to long wave theories stating that significant innovation is restricted to downturns.[730] The extent to which they resonate with micro level theories of innovation is difficult to assess as we lack information about the unique economic situation of the innovating firms. However, some general conclusions can be drawn with regard to the industry level, which will be discussed in section 8.3.

8.2 The small-firm innovation explosion

The issue of whether large or small firms (or medium-sized for that matter) account for the majority of innovations goes back to Joseph Schumpeter and is still a recurrent theme in studies of innovation activity. In the 1960s and 1970s academic scholars associated the mass consumerism seen after the World Wars with large firms.[731] The 1980s witnessed attention turning to the role of small firms in the economy.[732] Theory suggests that large firms benefit from resources and institutional backing while small firms benefit

[730] E.g. Mensch 1979

[731] Galbraith 1952, 1967; Chandler 1962. See also Chandler (1990).

[732] Birch 1979; Brock and Evans 1986, 1989; Acs and Audretsch 1988, 1989, 1990; Acs 1992; Audretsch 1995

from flexibility.[733] Conversely, large firms suffer from rigidity and small firms from a lack of resources and institutional support.[734] The Swedish economy is particularly dependent upon large firms.[735] Twenty large corporations account for half of total Swedish R&D expenditure.[736] In high-tech industries, eight large corporations account for 92 percent of total R&D expenditure.[737]

Findings presented in this thesis cast new light upon the role of small firms in the Swedish manufacturing sector. It was found that nearly half of the innovations observed in SWINNO were commercialized by small firms (0-49 employees), around a third by large firms (500- employees), and the remainder by medium-sized firms (50-499 employees). The distribution of innovations across the firm size spectrum is subject to significant variation during the period.

[733] Teece 1996

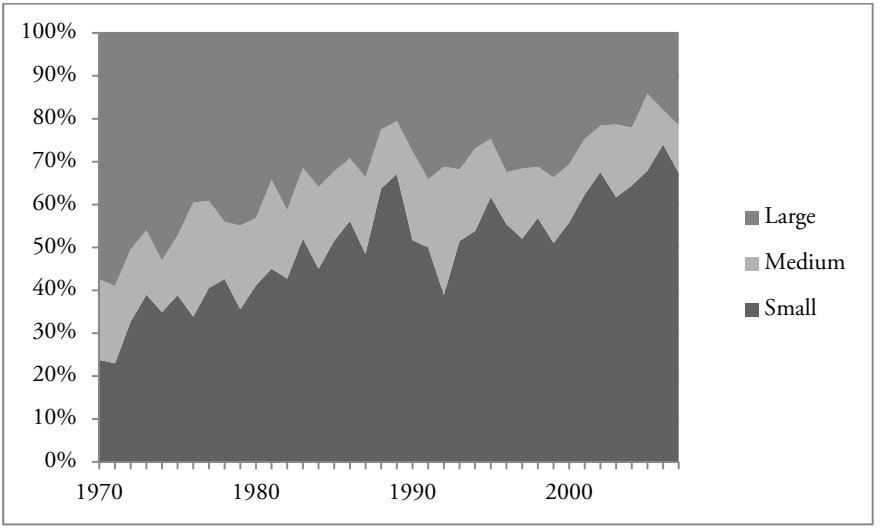
[734] Hannan and Freeman 1977, 1984, 1989; Leonard-Barton 1992; Freel 2000

[735] Jagrén 1993; Andersson et al. 2012

[736] Andersson et al. 2012

[737] Andersson et al. 2012

Figure 8.2 Distribution of innovations across firm-size classes, 1970-2007 (percent)



Small firm innovation experiences a tremendous increase. From accounting for one third of the innovations in the first six years of the period (1970-1975), small firms ultimately account for two thirds of the innovations in the new millennium.[738] The explosion of small firm innovation has come in two separate bursts; one in the 1980s and one following the 1990s crisis. Already established small firms drive the first increase whereas startup firms are responsible for the second. While startup firm innovations are nearly absent in the 1970s and only modest in the 1980s, such firms account for an annual average of 25 percent of the innovations commercialized in the period 2000-2007.

Small firms were found to commercialize more novel innovations in both relative and absolute terms than large and medium-sized firms. Large firms, conversely, were found to develop more innovations close to prior product offerings than small and medium-sized ones. Large firms seem thus to have been "sticking to their knitting" to a larger extent than smaller firms. This supposition is central in the organizational ecology literature and is referred to organizational inertia pertaining to hierarchies, complexity, and

[738] Annual averages.

inflexibility.[739] The SWINNO data gives empirical support to this supposition. However, an increase in highly novel innovations in large firm innovation output during the last sub period (1994-2007) suggests that large firms become increasingly explorative.

The large amount of new-to-the-world innovations seen in the 1980s is driven by small firms. However, the share of such innovations in the innovation output of large firms increases during this decade. This development is driven by large machinery and equipment firms and suggests an increasingly international focus in the innovation strategies of such firms during the 1980s.

8.3 Microelectronic receiver competence

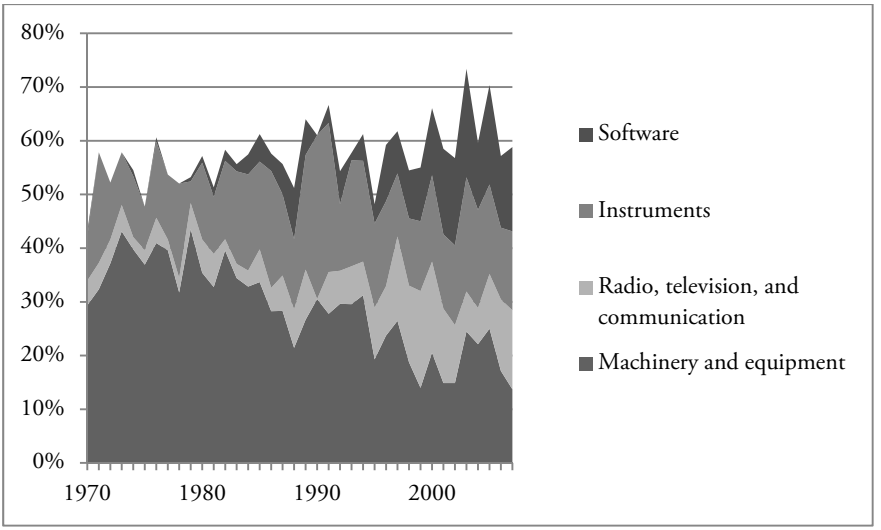
The period investigated in this thesis is characterized by the microelectronic revolution. Since the 1970s the microprocessor has come to transform the manufacturing sector through its seemingly infinite application possibilities.[740] The strong productivity growth throughout the OECD world in the second half of the 1990s and the 2000s has been attributed to the diffusion and application of cheap microelectronic components and the advancement of user competence.[741] Chapter seven explored how the field of microelectronics manifested itself in Swedish manufacturing innovation output.

[739] Hannan and Freeman 1977, 1984, 1989; Leonard-Barton 1992

[740] Freeman and Louça 2001 (ch. 9); Perez 2002; Castells 1998; Greenwood 1997

[741] Jorgenson and Stiroh 2000; Oliner and Sichel 2000; Crafts 2002; Gunnarsson et al. 2004; Mellander et al. 2005

Figure 8.3 Share of machinery and equipment, radio, television, and communication, instrument, and software innovations in total innovation output (percent), 1970-2007



The structural composition of innovation output changes from being dominated by machinery and equipment to being dominated by software, instrument, radio, television, and communication innovations (see figure 8.3). From around the turn of the millennium the increase in innovations from the latter industry categories levels of.

Whereas the share of microelectronic components in total innovation output is negligible there is a strong development on the application side.[742] All of the major contributors to total innovation output apply rather than develop microelectronics. It is thus suggested that with regard to microelectronics, the Swedish manufacturing sector was a *technology taker* rather than a supplier. While previous studies have shown that Swedish manufacturing firms were highly competent when it came to implementing and using microelectronics in their products and processes no prior study has, to the knowledge of this author, provided evidence of how the

[742] Microelectronic components is a subgroup of the category 'Radio, television, and communication equipment and apparatus' (SNI 32).

microelectronic revolution was manifested in the innovation output of the entire manufacturing sector.[743]

There was no rush of newly founded innovative firms into microelectronic-related industries in the 1970s and 1980s. With regard to the share of startup firm innovation in total innovation output, these industries did not differ notably from other industries. This finding refutes any claim that the development of microelectronic-related products in Sweden should have followed the stylized pattern of a so called industry life cycle or the proposition of several long wave theories, namely that nascent technologies engender entrepreneurial swarming.[744]

8.4 Transformation in the Swedish manufacturing sector, 1970-2007

Sweden enjoyed a high rate of economic growth during the first three quarters of the 20th century. To a large extent, this growth was fueled by the manufacturing sector. Accordingly, when growth slowed down in the mid-1970s observers turned to this particular sector for explanations. The sector was suggested to suffer from structural lock-in, rigidity, and inflexibility, in turn caused by severe institutional sclerosis and policy-induced misallocation or resources.[745] Conversely, the resumed growth rate in the second half of the 1990s and 2000s has been explained by far reaching institutional reforms that have had a positive influence upon the adaptive capacity of the manufacturing sector. This view has been expressed internationally as well as in accounts of Swedish origin.[746] In Sweden, scholars at Industriens

[743] Schön 1990; 2000; Eliasson 1980, 1987b, 1990b; Edquist and Jacobsson 1988; Ohlsson 1992

[744] Klepper 1997; Schumpeter 1934, 1942; Mensch 1979; Perez 2002; Freeman et al. 1982; Freeman and Louçã 2001

[745] Olson 1982, 1990, 1995, 1996; Ståhl and Wickman 1993, 1994; Tson Söderström 1994; Lindbeck et al. 1994; Andersson et al. 1993

[746] Calmfors 2013; Edquist and Henrekson 2013; Dougherty 2008; The Economist 2009; Irwin 2011; IMF 2012; Bergsten 2013

Utredningsinstitut (The Industrial Institute for Economic and Social Research, IUI) have been representatives of this viewpoint. The research tradition represented by these scholars has lately been called the Swedish growth school.[747]

This view has been challenged by the so called structural analytical perspective developed by economic historians first and foremost based at Lund University. This perspective is based on appreciative theorizing and poses that long term stagnation is associated with investments in renewal and is a prerequisite to a subsequent period of strong growth. Accordingly, the approximate period 1975-1995 is suggested to have been characterized by far-reaching investments in renewal. The results of this renewal took some time to materialize. After the crisis in the early 1990s the economy had rid itself of old unprofitable structures and the new ones were mature enough to become profitable.

The SWINNO database presents unprecedented opportunities to explore the range of differences between those two interpretations by prizing open the "black box" of micro level innovation output. Significant innovation is indicative of technological and/or strategic change and is as such a measure of transformation. Depending on the subject of investigation inferences of both schools receives support. Other results stand in contrast to accounts from both research traditions and provide an entirely new picture. This section will triangulate the subject matter of this thesis: transformation in the Swedish manufacturing sector, 1970-2007.

The first half of the 1970s is widely pictured as a period of rationalization with a strong focus on efficiency prevailing.[748] The SWINNO data supports this picture. Significant innovations were few in general and not many of those significant innovations were new to the world market. When it comes to the extent of transformation in the period running from the mid-1970s until the 1990s crisis, received accounts diverge. This thesis found a surge of innovation to have occurred in the years of acute structural crisis (1975-1982). While the innovation trend descends in the second half of the 1980s, it was discovered that firms were more explorative and came up with a

[747] Johansson and Karlsson 2002

[748] See chapter two, section 2.4.

higher share of innovations that were new to the world market in the 1980s than in any other period. It seems that on the aggregate level, the Swedish manufacturing sector responded to challenges posed by increased international competition and falling demand by stepping up innovation to levels previously unseen or additionally experienced thereafter.

These findings lend support to the structural analytical perspective and challenge the view held by the Swedish growth school. However, it turns out that when the data is disaggregated elements in the interpretation of *both* research traditions receive support or are at least not possible to reject on the basis of findings.

A central preoccupation of the Swedish growth school is the effect of the government subsidies given to firms in the crisis-ridden shipbuilding and iron and steel industries. The view is that the alternative cost of these subsidies was high; money should have been spent at the facilitation of entry and exit rather than providing artificial respiration to unprofitable firms.[749] In addition, subsidies and government ownership contributed to high wage costs in otherwise viable firms. This thesis found that innovation output from subsidized and subsequently nationalized firms in crisis-hit industries was meager and characterized by innovations in older rather than new domains. The government subsidies seem thus to have had little direct positive effect on the reorientation of the product portfolios of these firms. Structural inertia in crisis-hit industries can thus not be rejected on the basis of findings.

The majority of innovations in the 1970s and 1980s were found in the machinery and equipment industry. This finding was not surprising given that the industry, which counts a large number of the important large firms amongst its number, is widely considered to be the backbone of the Swedish economy. Intriguingly, large firm innovation is *less* dominant in this industry than in total innovation output. Both research traditions describe the extensive transformation of several of the large machinery and equipment firms.[750] However, the decline of innovation output in the

[749] Örtengren 1988; Jakobsson and Wohlin 1980; Eliasson and Lindberg 1988; Carlsson 1983a, b

[750] Eliasson and Lindberg 1988; Schön 1990, 2006a

second half of the 1980s offers support to the Swedish growth school which argues that creativity and commercializing competence weakened in this period.

The finding that small firm innovation outgrows other size classes' innovation output in the early 1980s is one of the most striking results presented in the thesis. The Swedish economy is generally reckoned to be heavily dependent on large firms. Both research traditions argue that institutions and policies had, for a long time, been designed to favor large firms.[751] While having a few sturdy locomotives of economic growth is not a bad scenario per se, the Swedish growth school argues that the 1970s and 1980s saw too little dynamism among the cars of the train, in particular surrounding insufficient entry and growth of small firms.[752] The structural analytical perspective is generally more positive about the sufficiency of dynamism in the small firm population but recognizes that institutions were not optimally designed to promote small business activity.

While the economic role of small firms was not assessed, it was found that to the extent that innovation drives transformation, small firms were behind the transformation wheel to an increasing degree from the beginning of and throughout the remainder of period. The share of small firm innovation in total innovation output grew from an annual average of 32 percent in the period 1970-1975 to an annual average of 61 percent in the period 1994-2007. Furthermore, small firms developed more novel innovations. *The received narratives have not captured the extent of this development*. While both research traditions argue that institutions were generally not designed so as to stimulate small firm activity, these findings suggest that institutions did not preclude the explosion of the small firm innovation share. However, there was little entry of innovative firms in the 1970s and 1980s, at least in comparison with the development of the coming decades. Hence, a central inference of the Swedish growth school's is supported by the SWINNO data.

The deep crisis in the first years of the 1990s marks the end of a period of slow GDP/productivity growth and the beginning of a period of relatively

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[751] Henrekson and Jakobsson 2000; Schön 2000 p. 473-4, 486-8

[752] Carlsson 1992b; Braunerhjelm and Carlsson 1993

strong growth. Intriguingly, the two research traditions describe the period after the crisis up until 2007 quite differently. Whereas according to the Swedish growth school, the period after the crisis is one of radical change and increased dynamism in the manufacturing sector, by contrast it is one of increasingly incremental change (especially in the new millennium) according to the structural analytical perspective. The poor development of total innovation output and the low level of novelty thereof give support to the structural analytical perspective. Chapter five discussed the possibility that the strong growth performance in the second half of the 1990s up until 2007 can be explained by lower prices on ICT products, the increased amount of learning about such technologies, and the diffusion of complementary and incremental innovations that fine tune them and make them more productive.[753] This possible long lag between innovation and growth is center stage in the structural analytical narrative.[754]

The growing importance of ICT is evident in the SWINNO data as total innovation output is largely driven by telecom and software products during the second half of the 1990s and the 2000s. The structural analytical perspective suggests that the character of innovations change in so called 'rationalization' periods (this particular one starting during the second half of the 1990s). In addition to becoming more incremental by nature, innovations also become increasingly complementary to each other and to established structures. One could argue that the change in innovation output, with a growing importance in the fields of telecom and software, confirms this generalization; telecom innovations increase connectivity in internet, wired, and wireless communication while software products add value to hardware.

Software innovation output as a category is heavily composed of startup innovations. No less than 40 percent of the software innovations in the new millennium were commercialized by newly founded firms. The recent dynamic in this and other microelectronic-related industries is well reflected in Swedish growth school accounts where it is explained by a set of

[753] See for example David (1990), Oliner and Sichel (2000), Jorgenson and Stiroh (2000), (Crafts 2002), Gunnarsson et al. (2004), Mellander et al. (2005)

[754] Schön 1990

institutional changes.[755] Great importance is attached to greater access to venture capital, the neutralization of the tax system brought about by the large tax reform in 1990/1991, and other institutional changes in favor of entrepreneurial activity and small firm investment. These institutional changes were not implemented overnight, the reformation of the tax system had begun in the 1980s and the credit market was deregulated gradually during the same decade. The strong increase of startup innovation found to have taken place after the 1990s crisis lends credibility to this viewpoint. Hence, with regard to the growing importance of ICT related innovations, the strong growth of small firm and startup innovation in the period 1994-2007, the Swedish growth school seems to provide an apt picture.

To conclude, the Swedish growth school and the structural analytical perspective both contribute to our understanding of the process of structural transformation in the Swedish manufacturing sector 1970-2007. Whereas the interpretations of the two research traditions are in some respects contradictory, they are complementary in others. Contradictory as well as complementary aspects of both may be explained by different points of emphasis, in particular with regard to level of analysis. The thorough examination of micro level innovation output presented in this thesis is a new source of knowledge concerning the process of industrial transformation. Some results support received analyses while others suggest a revision of the picture of this process.

8.5 Some concluding remarks

Based on this summary of findings regarding transformation in the Swedish manufacturing sector it is suggested that, to the extent that innovations of the kind studied in this thesis reflect an important aspect of transformation, the dominating assumptions concerning this process in Sweden between 1970 and 2007 must be revised. Following decades of strong growth the Swedish economy stagnated and grew only slowly in the second half of the 1970s through the 1980s. A view widely held, domestically as well as internationally, is that the poor growth reflected structural lock-in. This

[755] Johansson 1999a, b; Edquist and Henrekson 2013

thesis has shown that this inference is what Erik Dahmén would have called a "fallacy of aggregative thinking". The growth rate does not reflect unanimous lock-in on the micro level. Instead, the slow growth masked intense innovation activity in parts of the manufacturing sector. Conversely, the recovery and the resumed growth rate of the Swedish economy in the 1990s and 2000s were not associated with a flurry of significant innovations. The quantitative and qualitative changes in innovation output and their temporal relationship to long term fluctuations in economic growth suggest that we have to look behind aggregate statistics. Analyses of processes of structural transformation should preferably combine micro and macro level perspectives. A one sided preoccupation with one of the levels could cause unfortunate myopia or hyperopia. We wish to be able to see both the full picture at some distance and the intricate details that comprise it. Moreover, we may have to apply a longer time perspective if we wish to understand transformation processes as indeed, they unfold over extensive time periods rather than merely a few years. Furthermore, the findings of this thesis suggest that we should reconsider innovator locus. We should attempt to avoid the giants standing in the way of our understanding of the role of small firms in the process of structural transformation.

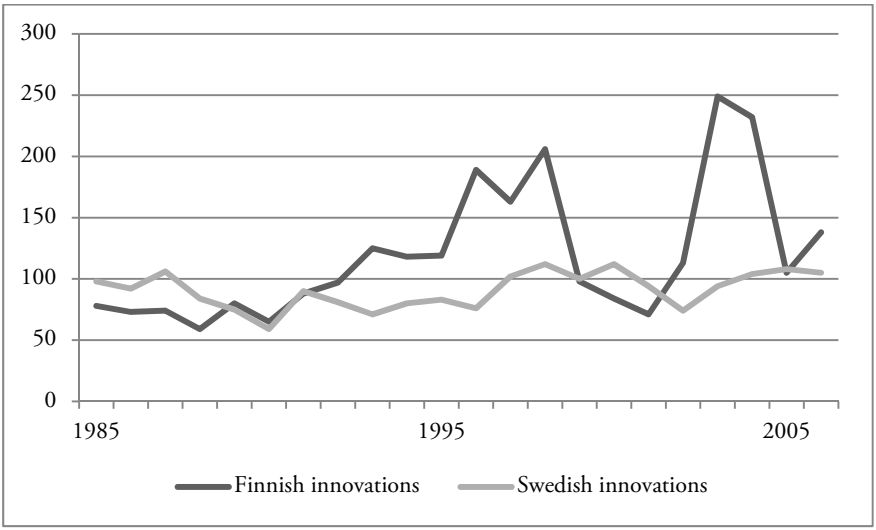
The next section will highlight some directions for future research.

8.6 Future research

The author of this thesis comfortably concludes that the presented findings have generated a set of new research questions. One of the more obvious questions regards the meager innovation output of the 1990s and 2000s as compared to that of previous decades. Is the Swedish manufacturing sector really becoming less innovative? Are innovations in the last two decades of the period potentially more valuable on average? If so, that could compensate for their lower aggregate number. Another possibility is that innovations in recent decades are merely different and therefore not captured in SWINNO. Future research could start out from these three possibilities. A comparison between the SWINNO data and the Finnish counterpart SFINNO could serve as one point of departure. Both Sweden

and Finland are time and again found in the top of the Innovation Scoreboard published by the European Union, and together are two of the most R&D intensive economies in the union.[756] Furthermore, there is considerable resemblance in the industrial structure of the two countries.[757] However, the development of Swedish and Finnish innovation output is strikingly different. Figure 8.4 shows that Finnish innovation output has developed with stronger momentum than innovation output in Sweden since the early 1990s, except for a big slump which occurred around the turn of the millennium.

Figure 8.4 Finnish and Swedish innovations (n), 1985-2006



Source: SFINNO™

Given that Swedish and Finnish trade journals capture the same kind of innovations and have developed similarly, the trend differences are striking and should generate more endeavors eager to understand what explains the comparatively weak performance of Swedish innovation output.

[756] European Commission 2005, 2008, 2013

[757] Andersson and Krantz 2006; Hagberg et al. 2006

One way this could be undertaken would be to approach the value and character of the Swedish innovations through surveys sent to the innovating firms. Questions could for example address the particular type of innovation's role in firm sales or turn over in one, five, and ten years after the commercialization. In addition, a survey sent to the innovating firms could also ask questions about the innovation process and the financing thereof. Such questions could for example shed light on whether the decreasing R&D productivity observed in chapter five could be explained by longer, more complex and expensive development processes. Questions related to the role of external capital (e.g. venture capital and R&D subsidies) could make a starting point for a study of the role and effects of institutional change on innovation. Again, a comparison with Finland could be relevant since Finnish and Swedish innovation policy and institutions differ in some important respects.[758] Surveys could also be used to assess the extent to which SWINNO fails to capture specific types of innovations. Another way to investigate the possibility that the meager innovation output is due to methodological shortcomings is to consult industry experts.

Future research should also dig deeper into the development of the innovation output of firms of different sizes. One potential research option could concern itself with the absolute and relative decline of large-firm innovation output. Where did all the large firm R&D expenditure go? How do we capture a potential increase in system and service innovation? Answering questions related to the innovation regimen of large firms may require complementary data such as interviews, annual reports etc.

Another question takes its point of departure from the observation that large firms are still the backbone of the Swedish economy, despite a dominance of small firm in total innovation output. What happened to all the innovating small firms; were they more likely to survive and/or did they tend to grow more than the non-innovating small firm? Previous studies have shown both a weak inclination to grow among small Swedish firms and that small-firm acquisition was a widespread innovation strategy of large firms in the 1980s.[759] Additionally, the possibility that innovating small firms are *de jure*

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[758] Blomström et al. 2002

[759] See Henrekson and Johansson (1999b) for a review of such studies investigating small firm growth. See Jagrén (1988; 1993) regarding the large-firm acquisition of small firms. It has

independent but *de facto* closely linked to a large firm through for example a supply-chain relationship should be investigated.[760] A systems or network perspective could be applied in order to investigate whether firms of different sizes (in different industries, regions etc.) are linked. Formal collaboration on innovation as well as other links should be explored. Looking into the activities, performance, and the fate of innovating small firms could contribute to our understanding of the role these firms play in the economy.

One final suggestion for future research would be an investigation of the quantitative and qualitative development patterns of innovations during and beyond the recent slowdown of the world economy. The structural analytical perspective characterizes the slowdown as a structural crisis. According to the periodization suggested by the structural cycle, such a crisis is followed by a transformation period. An extension of the database would reveal if there is such cyclicality in the innovation data; if it transpires that indeed there is, the number, novelty, and character of innovations should increase remarkably in the coming years according to the theory. The Swedish growth school would likewise propose an increase in innovation, but would attribute it to institutional changes (e.g. more elaborate entrepreneurship policy) rather than mechanisms inherent in the industrial capitalist system.

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been suggested that being a large firm is disadvantageous in the early stages of innovation processes, but an advantage later (Williamson 1975). The opposite may apply to small firms. Less hierarchy and more flexibility may facilitate concept development, while resource constraints may constrain large scale production and marketing. An acquisition may thus be a bargain for both the acquired and the acquirer.

[760] See Harrison (1994) and Andersson and Lööf (2012).

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Appendix A

Table A.1 Top Swedish firms' position vis-à-vis top foreign competitors in the 1940s, 1950s, 1960s, and 1970s

Source: Carlsson et al. 1979 p. 146-150. Note: Based on a survey sent first and foremost to members of IVA (The Royal Swedish Academy of Engineering Sciences).

Industry	Decade	Position vis-à-vis top competitors		
		Ahead	Equal	Behind
Crude steel	1970s			X
	1960s			X
	1950s		X	
	1940s		X	
Special steel	1970s		X	
	1960s	X		
	1950s	X		
	1940s	X		
Wood	1970s	X		
	1960s	X		
	1950s	X		
	1940s	X		
Forest machines	1970s	X		
	1960s	X		
	1950s			X
	1940s			X
Refractory ceramics	1970s		X	
	1960s		X	
	1950s			X
	1940s		X	

Textile and apparel	1970s		X	
	1960s		X	
	1950s		X	
	1940s		X	
Petro-chemicals	1970s		X	
	1960s			X
	1950s			X
	1940s			X
Basic plastics	1970s		X	
	1960s			X
	1950s			X
	1940s			X
Plastic pipes	1970s	X		
	1960s		X	
	1950s		X	
Liquid injection molding	1970s		X	
	1960s	X		
	1950s		X	
Organic chemistry	1970s		X	
	1960s		X	
	1950s		X	
Pharmaceuticals	1970s	X		
(production methods)	1960s		X	X
	1950s			X
Intravenous nutrition	1970s	X		
	1960s	X		
	1950s	X		
	1940s	X		
Canned food	1970s			X
	1960s			X
	1950s			X
	1940s			X

Deep-frozen food	1970s	X			
	1960s	X			
	1950s	X			
	1940s	X			
Sugar	1970s		X		
	1960s	X			
	1950s	X			
	1940s	X			
Packing of liquid foodstuff	1970s	x			
	1960s				X
	1950s				X
Foodstuff machinery and equipment	1970s	X			
	1960s		X		
	1950s		X		
	1940s		X		
Shipbuilding	1970s	X			
	1960s	X			
	1950s	X			
Shipbuilding methods	1970s		X		
	1960s	X			
	1950s	X			
	1940s	X			
Marine steam turbines	1970s	X			
	1960s	X			
	1950s				X
	1940s				X
Aero motors	1970s		X		
	1960s		X		
	1950s				X
	1940s				X

Aircraft	1970s		X		
	1960s		X		
	1950s		X		
	1940s				X
Power current	1970s	X			
	1960s	X			
	1950s		X		
	1940s		X		
Power supply (transmission and coordination of grids)	1970s	X			
	1960s	X			
	1950s	x			
	1940s		X		
AC power transmission	1970s	X			
	1960s	X			
	1950s	X			
DC power transmission	1970s	X			
	1960s	X			
	1950s	X			
	1940s	X			
Other technologies related to power direction	1970s	X			
	1960s	X			
	1950s	X			
	1940s		X		
Information processing and surveillance of power grids	1970s	X[761]			
	1960s		X		
	1950s				X
	1940s				X

[761] Not before the U.S.

Electrical locomotives	1970s	X			
	1960s		X		
	1950s			X	
	1940s			X	
Automatic circuits for telecommunications sytems	1970s	X[762]	X[763]		
	1960s	X			
	1950s	X			
	1940s	X			
Telephones	1970s	X			
	1960s	X			
	1950s	X			
	1940s		X		
Transmission technology (telephones)	1970s	X			
	1960s	X			
	1950s	X			
	1940s		X		
Automatic block terminals	1970s	X			
	1960s		X		
	1950s	X			
	1940s		X		
Semiconductor technology (knowledge, not application)	1970s		X		
	1960s		X		
	1950s			X	
	1940s			X	

[762] The end of the 1970s.

[763] The beginning of the 1970s.

Appendix B

Figure B.1 Total number of 'Machinery and equipment' (SNI 29) innovations and the number of such innovations in Ny Teknik, Automation, and Verkstäderna 1970-2007

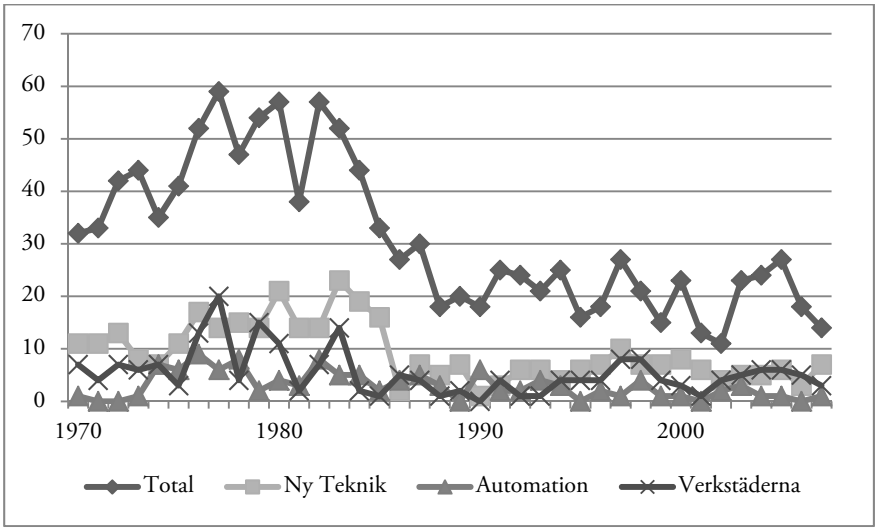


Figure B.2 Total number of 'Radio, television, and communication' and 'Software' (SNI 32+72) innovations and the number of such innovations in Ny Teknik, Elektroniktidningen, and Telekom Idag, 1970-2007

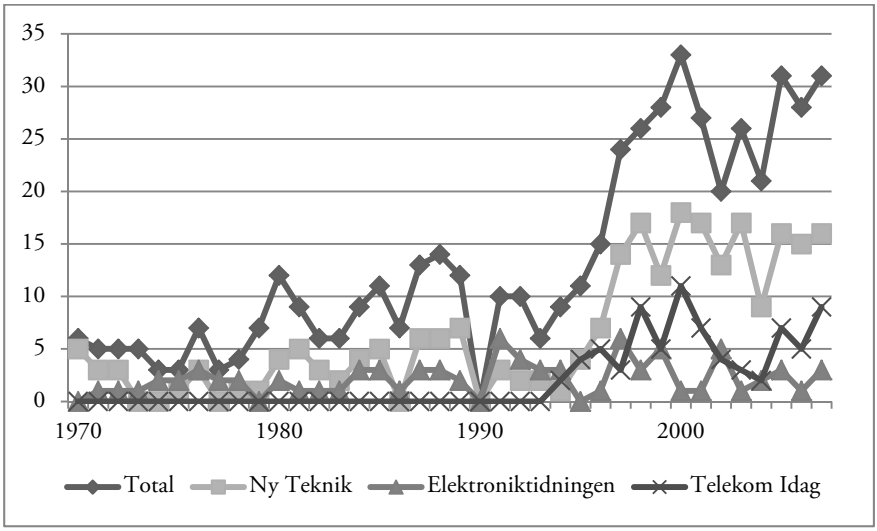
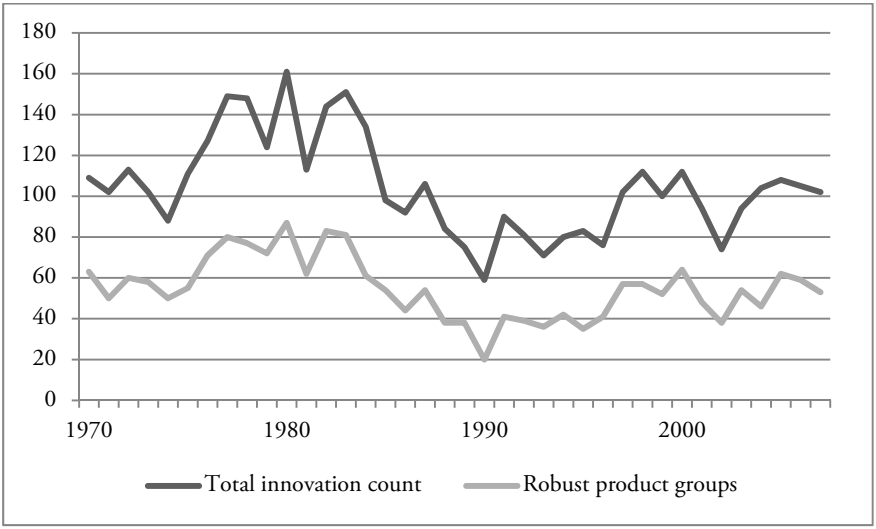


Figure B.3 Total number of innovations and 'robust' product groups



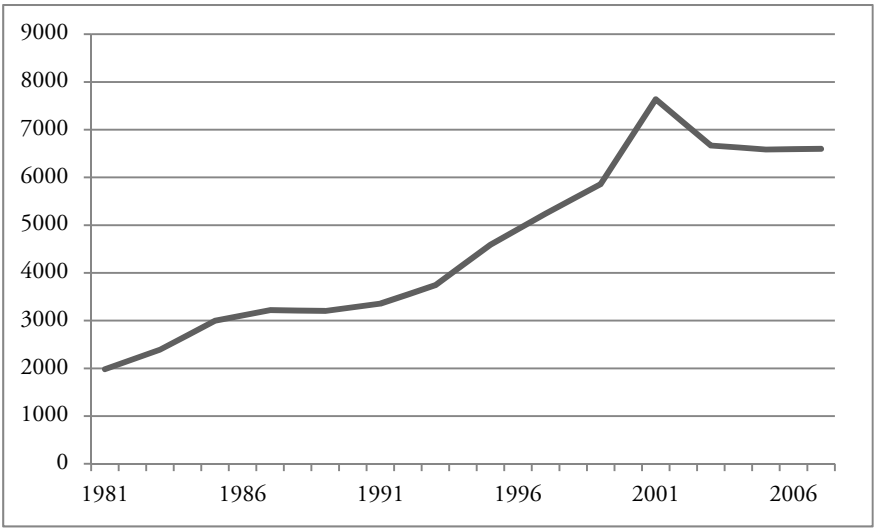
Note: Robust product groups are 'Rubber and plastics' (SNI 25), 'Fabricated metal products' (SNI 28), Machinery and equipment' (SNI 29), 'Radio, television, and communication equipment and apparatus' (SNI 32), and 'Computer and related activities' (SNI 72). These product groups were robust with regard to arbitrariness in the choice of journals.

Table B.1 Large firms and the principles followed with regard to changes in firm names

Firm	Principle followed
Asea/ABB	Includes all subdivisions in ASEA until 1988 and from after the merrger with Swiss company Brown Bover in ABB.
Astra	Astra throughout the period despite merger with British pharmaceutical company Zeneca in 1999.
Billeruds	From 1978 Billerud Udddeholm.From 2002 Billeruds.
Billerud Uddeholm	From 1984 Stora.
Eka	From 1986 Nobel Industries.
Ericsson	Until 2001 with mobile communication.
Fagersta	Until 1974 including Seco Tools.
Gränges	Until 1978 including Oxelösunds Järnverks.
Kabi	From 1972 Kabi Vitrum
Kabi Vitrum	From 1990 Pharmacia
KemaNobel	From 1984 Nobel Industries.
KemaNord	From 1978 KemaNobel.
Kockums	Från 1979 Svenska Varv. Från 1989 Kockums.
Nitro Nobel	From 1978 KemaNobel.
Nobel Industries	Nobel Industries throughout the period despite being acquired by Dutch chemical company Akzo in 1994.
Norrbottens Jernverk	From 1978 SSAB.
Saab	Until 1978 including Datasaab. Until 1990 including private car manufacturing. Until 1996 including Scania. Until 2001 including Tank Radar.
Stora	Between 1984 and 2002 including Billerud. From 1978 without Domnarvets Jernverk and the majority of the mines.
Uddeholm	From 1978 Billerud Uddeholm. From 1991 Uddeholm.
Volvo	Until 1999 including all subsidiaries. From 1999 without private car manufacturing (acquired by Ford).

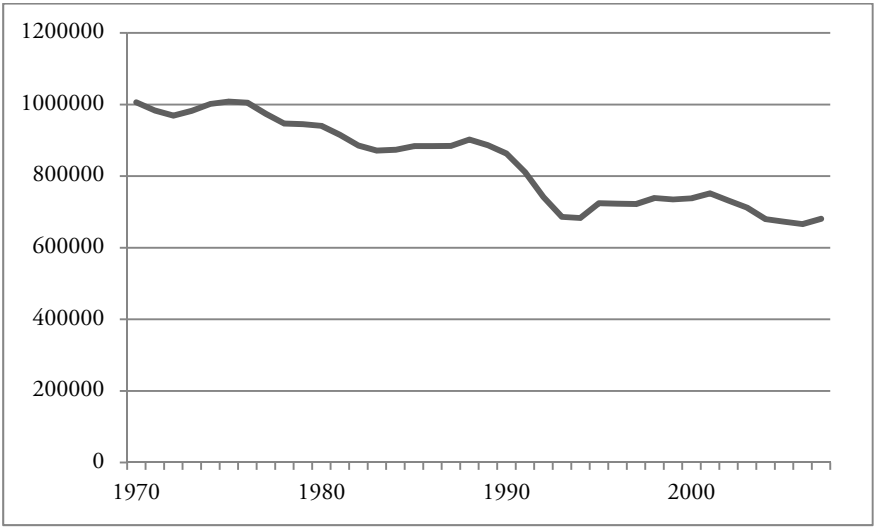
Appendix C

Figure C.1 Million dollar business enterprise R&D, 1981-2007 (constant prices)



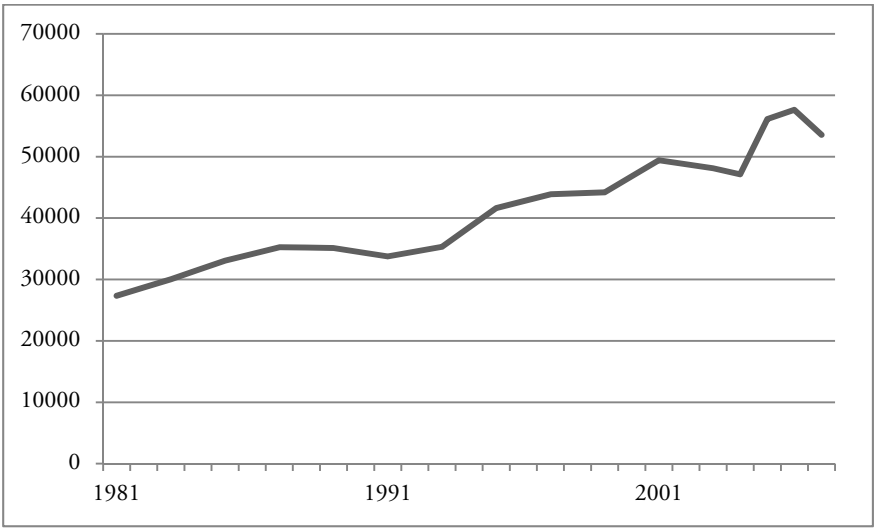
Source: OECD. 2005 price level. The OECD business enterprise R&D data contains observations of expenditures every two years between 1981 and 2007. Values for the missing years were retrieved through linear interpolation.

Figure C.2 Manufacturing sector employees, 1970-2007



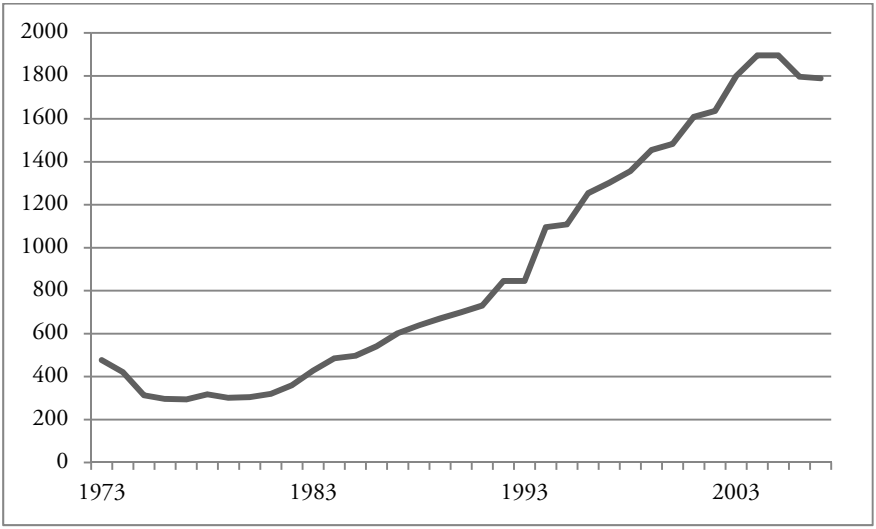
Source: OECD.

Figure C.3 Total business enterprise R&D personnel, 1981-2007



Source: OECD. The OECD data contains observations of total R&D personnel every two years between 1981 and 2003. Values for the missing years were retrieved through linear interpolation.

Figure C.4 Engineering doctorate and licentiate degrees, 1973-2007



Source: Statistics Sweden

Appendix D

The structure of the Swedish firm population has undergone substantial changes between 1970 and 2007. The objective of this appendix is to illustrate the major trends. The accounts that will be reviewed regard both changes in the number of firms and changes in the distribution of employment across firms of different sizes. Different periodization, groupings and definitions of size classes aggravate comparisons and make a coherent presentation a challenging endeavor. The review starts out with the numerical development of firms in different size classes and proceeds with the distribution of employment over firms in different size classes.

Statistics Sweden started a firm register in 1963. From 1968 onwards, the register begins recording firm size. Regrettably, given the decision taken to treat subsidiaries as part of corporate groups (see chapter four, section 4.6.2), the Business Register did not satisfactorily separate independent and subsidiary firms until 1984. Hence, a review of the period of development up until 1984 is compelled to rely upon data unadjusted for corporate groups. The period following 1984 is however covered in depth by accounts based on corporate group adjusted data.[764] Note that the size classes in the cases that are reviewed in this appendix differ from those used in the empirical chapters of the thesis.

Both Johansson (1997) and Henrekson and Johansson (1997) investigate changes in the number of manufacturing firms between 1968 and 1993.[765] The authors report a decline in the number of firms between 1968 and 1982

[764] See e.g. Johansson (1997), Henrekson and Johansson (1997), Henrekson and Stenkula (2006), Henrekson et al. (2012).

[765] Note that the data used in Johansson (1997) and Henrekson and Johansson (1997) is unadjusted for corporate groups.

in all size classes except sole proprietorships and large firms.[766] This pattern seems to support the widely held view that the 1970s was characterized by rationalization, mergers, and acquisitions. The post-devaluation 1980s saw a positive development of the number of firms in the majority of size classes. Possible explanations of this pattern include the expansion of credit and the increase of capital in circulation which characterized this decade.

[766] Johansson (1997) and Henrekson and Johansson (1997) consistently report the smallest size class as representing firms with 0-1 employees. When discussed in the text of these works, this size class is found to be inhabited mainly by sole proprietorships (Johansson 1997 p. 8). Johansson's (1997) and Henrekson and Johansson's (1997) smallest size class is therefore, for the sake of consistency in this presentation, referred to as zero employee-firms (i.e. sole proprietorships). Furthermore, sole proprietorships pose a statistical problem in Johansson's (1997) presentation. A methodological shift is argued to have greatly inflated the number of such firms (Johansson 1997 p. 8). Changes in the smallest class (0 employees) shall thus be considered not in terms of levels but in terms of a trend. Another such database named Compendia (COMParative ENtrepreneurship Data for International Analysis), put together by EIM Business and Policy Research in the Netherlands, also counts the number of sole proprietorships (between 1972 and 2004) (van Stel 2008). The Compendia data draws on a set of sources (e.g. OECD) and tries to handle some of the major measurement problems (e.g. changing definitions and trend breaks) with the aim of producing comparable data for 23 OECD countries. Henrekson and Stenkula (2006 p.43) present Compendia data that paints an alternative picture to that presented in table D.1 Sole proprietorships as a share of the entire workforce decrease until the late 1970s, subsequently increasing with a peak occurring around 1983 from where it begins decreasing again until the eruption of the financial crisis in the early 1990s. After the crisis it increases again throughout the remainder of the 1990s to level off around the turn of the century. An important caveat however, is that the Compendia data presented by Henrekson and Stenkula (2006 p. 43) reports total sole proprietorship, not solely that within the manufacturing sector. With regard to changes in the number of the largest firms, they should also be interpreted cautiously since the data is not adjusted for corporate groups. A tentative interpretation of the slight increase in the number of large firms could suggest that it is a reflection of the divisionalization zeal discussed in chapter four. See Henrekson and Stenkula (2006).

Table D.1 Change in the number of manufacturing firms per million inhabitants, 1968-1993 (percent)

	Size class (number of employees)								
	0*	1-4	5-9	10-19	20-49	50-99	100-199	200-499	500-
1968-1982	191	-15	-8	-14	-13	-8	-12	-6	5
1982-1990	36	24	5	6	2	-4	6	9	4
1990-1993	-27	-8	-10	-24	-21	-17	-26	-17	-21

Note: Data unadjusted for corporate groups. * refers to sole proprietorships. Source: Johansson 1997 p. 13 (based on data from Statistics Sweden).

Braunerhjelm and Carlsson (1993) perceive the development of the number of firms during the 1970s and 1980s differently. According to these authors, the total firm population contracted during this period. The decrease is by and large attributed to those classes inhabited by the smallest firms (1-9 employees) which are shown to have decreased by some 80 percent.[767] Furthermore, the only firms growing under this period are those with more than one hundred employees. Elsewhere, Carlsson (1992b) reports that plant size increases during the period. Braunerhjelm and Carlsson (1993) suggest several explanations of the decreasing number of small firms; they may have grown into another size class, or they may have been acquired by another firm, or a large number of small firms may have been shut down. In summary, the message given by Braunerhjelm and Carlsson (1993) is that the 1970s *and* 1980s are characterized by increasing concentration.

The partly contradicting accounts reviewed above renders the provision of a uniform picture of firm population development during the 1970s and 1980s a difficult task. The key point on which Johansson (1997) and Henrekson and Johansson (1997) on one side of the argument, and Braunerhjelm and Carlsson (1993) on the other, differ is with regard to the development of small firms during the 1980s. While the former group displays positive development, the latter paint a gloomier picture with regard

[767] Braunherhelm and Carlsson 1993 p. 321. The period referred to is more precisely 1968 to 1988.

to this category. Other accounts complement Johansson and Henrekson by questioning the dominant role of large firms during the 1980s.[768] Davidsson et al. (1996) point out that as much as 50 percent of the gross increase in the number of jobs in the 1980s took place at the level of small firms.[769]

The corporate group adjusted firm data presented by Henrekson and Stenkula (2006) shows a mixed picture. The smallest firms increase, while firms with 10-49 employees decrease. Hence, Henrekson and Stenkula (2006) offer partial support to both Johansson (1997) and Henrekson and Johansson (1997) on the one hand, and Braunerhjelm and Carlsson (1993) on the other.

Table D.2 Manufacturing firms per million inhabitants, 1984-2004

	Size class (number of employees)			
	1-9	10-49	50-199	200-
1984	1495	537	116	39
1993	1651	422	85	39
1997	1690	497	104	46
2004	1725	517	105	45

Note: Adjusted for corporate groups. Sole proprietorships are excluded by the authors (Henrekson and Stenkula 2006 p. 21) because of statistical problems. Source: Henrekson and Stenkula 2006 p. 21 (based on data from Statistics Sweden).

While size classes 10-49 and 50-199 employees decrease from the 1980s and until the conclusion of the 1990s crisis they experience a positive trend from 1993 onwards. The period from 1997 onwards is positive with regard to all sizes classes except the largest firms, who stagnate in number from 1997 onwards.

The corporate group adjusted employment data presented in table D.3 and D.4 displays the dominance of large firms described in chapter three. With regard to the development of the small firm size classes (1-9 and 10-49 employees) during the 1980s, the employment data tells us that relatively more people were hired by firms with 1-9 employees and less by firms with

[768] Davidsson et al. 1996 p. 13

[769] Ibid.

10-49 employees (D.3). The relative development of employment in medium-sized firms is also split, the larger firms in this spectrum hire a larger share and the smaller a smaller share. Employment in large firms (>500 employees) decreased somewhat between 1984 and 1993.

Table D.3 Distribution of manufacturing employment over firm size classes, 1984-1993 (percent)

	Size class (number of employees)				
	1-9	10-49	50-199	200-499	500-
1984	5.5	11.3	10.9	6.9	65.5
1993	6.7	10.6	9.7	9.1	63.8

Note: Adjusted for corporate groups. Sole proprietorships are excluded due to statistical problems. Source: Henrekson et al. 2012 p. 29 (based on data from Statistics Sweden).

Table D.4 Distribution of manufacturing employment over firm size classes, 1993-2009 (percent)

	Size class (number of employees)				
	1-9	10-49	50-199	200-499	500-
1993	8.0	12.3	11.3	10.4	58.0
1999	7.1	12.4	11.7	10.0	58.7
2004	7.3	13.3	12.5	10.1	56.9
2009	7.8	14.5	14.4	11.8	51.5

Note: Adjusted for corporate groups. Sole proprietorships are excluded because of statistical problems. Differences in the 1993 numbers in table D.3 and D.4 are due to data revision and the exclusion of a couple of legal forms of organization. Source: Henrekson et al. 2012 p. 29 (based on data from Statistics Sweden).

There are two sustained employment trends in the period running from 1993 to 2009; the large firm employment share continues to fall and the employment figures in firms with between 10 to 499 employees consistently rises. The decrease of the share in large firm employment is partly explained by the acute difficulties experienced by this size class during the early 1990s crisis.[770] However, this decline had evidently begun in the 1980s. It has been noted that there was a decrease not only in relative terms, but also in terms

[770] Davidsson et al. 1996

of the absolute number of employees within large firms; over the period 1977-2005, corporate groups experienced a loss of some 280 000 in the number employed.[771] The reduction in large firm employment could for example be accounted for through the relocation of jobs to foreign countries and outsourcing in general.[772]

Swedish startup activity has been studied separately and enjoys a long tradition going as far back (at least) to Dahmén's PhD thesis published in 1950. Dahmén found that the interwar period was one of intense entrepreneurial activity in the 'Schumpeter mark I' sense of the term. In later contributions Du Rietz (1975, 1980) shows that startup activity was indeed intense up until the mid-1960s, from where it subsequently decreased. Other studies have concluded that this decrease continued into the first years of the 1970s.[773] Regrettably, our understanding of the effect of the early 1980s' incipient institutional reforms on startup activity suffers from a lack of data. Statistics Sweden keeps a record of newly founded firms since 1985 and there is thus an unfortunate gap in the data.[774] Furthermore, comparing the earlier studies with the latter day Statistics Sweden data is difficult due to changes of definitions and inclusion criteria.[775]

Statistics Sweden's data shows that the number of manufacturing startups decreased during the second half of the 1980s and plummeted during the first years of the financial crisis in the early 1990s.[776] Startup activity increased markedly between 1992 and 1994; an increase which is possibly due to necessity rather than opportunity based entrepreneurship, given the

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[771] Bjuggren and Johansson 2009. The loss of jobs suffered in large firms has been attributed to the export of jobs to low-wage countries and the reclassification of production activities into service activities as firms streamline their business (Bjuggren and Johansson 2009).

[772] Harrison 1994; Andersson et al. 2012

[773] Odén 1976

[774] The firms recorded by Statistics Sweden are defined as those whose activity has recently commenced or whose activity has rebounded after having been dormant for *at least* two years. The definition includes firms whose primary activity is something that the founder previously engaged in as an employee.

[775] Braunerhjelm and Carlsson 1993

[776] Braunerhjelm and Carlsson 1993; Braunerhjelm and Thulin 2010 p. 40.

high level of unemployment.[777] From the level reached in 1994, the startup share (startups divided by the total number of firms) decreases until 2004 when it sees a slight increase. In terms of the number of startups per 1000 employees, the level is more or less constant from 1990 throughout the period (until 2007).[778] With regard to the number of employees in newly started firms, there is a slight decrease between 1990 and 2007.[779]

New technology-based firms comprise a subset of the startup category.[780] A new technology-based firm is defined as "a firm whose strength and competitive edge derives from the know-how within natural science, engineering or medicine or the people who are integral to the firm and upon the subsequent transformation of this know-how into products and services for a market".[781] The definition centers not on the level of novelty of the technology in question but on the competencies of the employees. Prior to 1975 such firms were scarce and had little (although positive) impact on Swedish industrial renewal.[782] The stock of new technology-based firms is estimated to have nearly doubled between the mid-1980s and 1993, despite the financial crisis between 1991 and 1993.[783] Although the stock of firms did not grow significantly during the crisis, new technology-based firms managed to increase their number of employees by 26 percent between 1991 and 1993, a period during which hundreds of thousands of jobs within manufacturing disappeared.[784] Regrettably, the author could locate no studies which identified new technology-based firms or which estimated their contribution to Swedish industrial renewal during the period 1993-2007.

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[777] Braunerhjelm and Thulin 2010 p. 40

[778] Braunerhjelm and Thulin 2010 p. 41

[779] Ibid.

[780] Rickne and Jacobsson 1996, 1999. Rickne and Jacobsson's (1999) sample includes not only manufacturing firms but also manufacturing-related service firms.

[781] Rickne and Jacobsson 1999 p. 203

[782] Rickne and Jacobsson 1996

[783] Rickne and Jacobsson 1999 p. 212

[784] Rickne and Jacobsson 1999 p. 213

One type of firm adjacent to that of new technology-based firms is that variety based on academic entrepreneurship. This thesis considers only academic spin off *firms* as academic entrepreneurship can imply a much wider range of activity than the mere creation of new firms.[785] Furthermore, this thesis considers only the situations when a PhD student or a faculty member starts a firm directly drawing on the results of research or alternatively when research results are commercialized by an existing firm. Lindholm Dahlstrand (2008) estimated that between 1975 and 1993 approximately 200 firms were newly established by researchers who left their academic homestay annually. Furthermore, there are those firms that were started by researchers sometime after they had left academia. Lindholm Dahlstrand (2008) estimated that around 400 such firms commenced business annually during the same period. Jacobsson et al. (2013) report an annual average of 300 firms started by former university researchers between 1997 and 2009.[786]

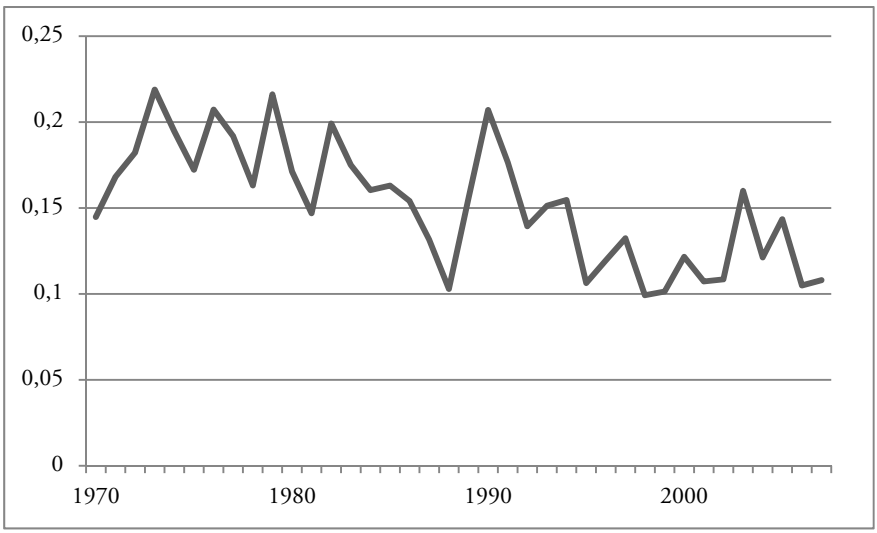
In summary, this review of the development of the structure of the firm population has shown that the number of small and medium sized firms grows while the number of large firms is relatively stagnant. Large firms are still heavily dominant with regard to employment although the trend is on a negative trajectory. No consensus was reached with regard to the timing of the beginning of the positive development of small firms. The underlying pattern during the 1980s is particularly contested. Furthermore, the reviewed literature reported only modest rates of startup activity throughout the period.

[785] Klofsten and Jones-Evans 2000; Rothaermel et al. 2007

[786] Jacobsson et al. (2013) report firms that were established within the same year as that in which the researcher(s) in question left university.

Appendix E

Figure E.1 Industry origin concentration, 1970-2007 (HH index)



Note: The index shall be interpreted so as the higher the number the higher the concentration of innovations to a few industries, and vice versa.

The index shows that the increasing heterogeneity in terms of industry origin is cutting through the data, save for a temporary reversal during the early 1990s.[787] The reversal is quite possibly a reflection of the patterns found in chapter six; fewer firms in general contribute to the total innovation output and the most frequent innovators step up and develop a larger share of the innovations during these years. At the same time, the

[787] The Herfindahl-Hirschman index is calculated according to the following formula: HHI = $\sum p_i^2$ where p_i is the industry's share of the total innovation output in one year.

number of innovations drops which in turn means that the innovations to be distributed over the industries are fewer.

Figure E.2 'Office machinery and computer' (30) innovations, 1970-2007 (n)

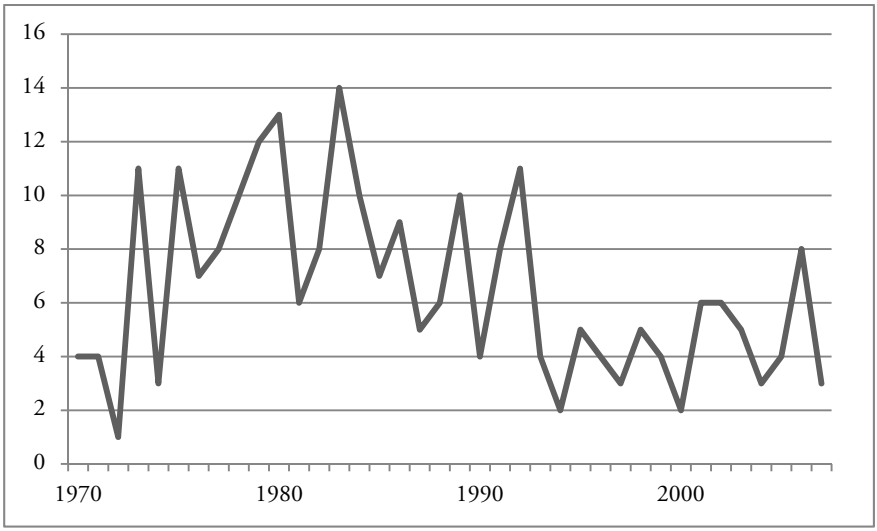


Figure E.3 'Radio, television and communication equipment and apparatus' (32) innovations, 1970-2007 (n)

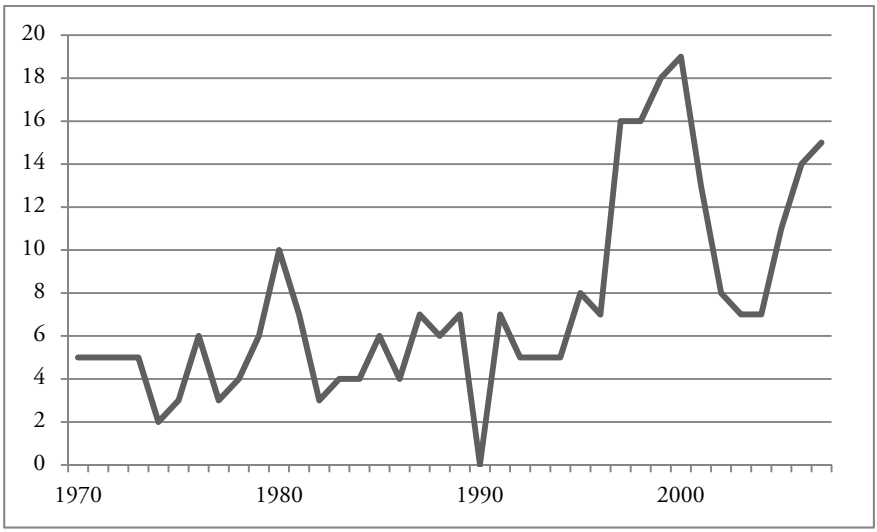


Figure E.4 'Medical, precision, and optical instruments, watches and clocks' (33) innovations, 1970-2007 (n)

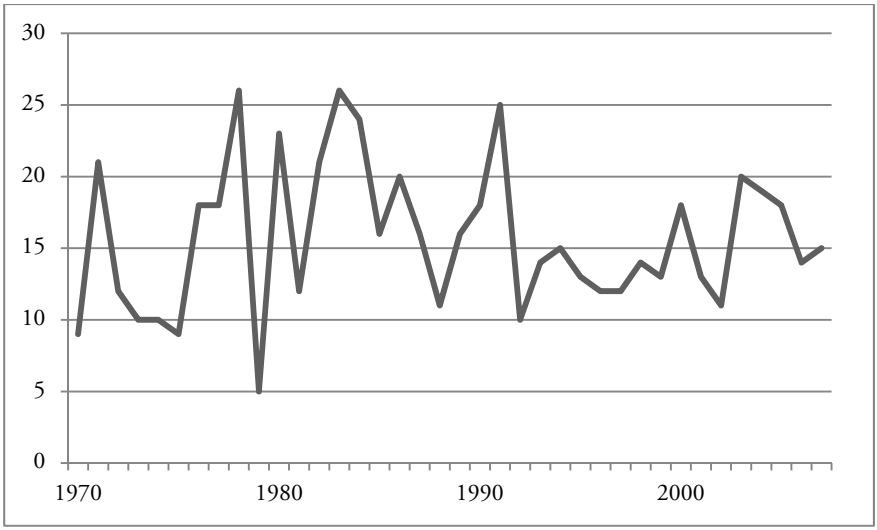


Figure E.5 'Computer and related activities' (72) innovations, 1970-2007 (n)

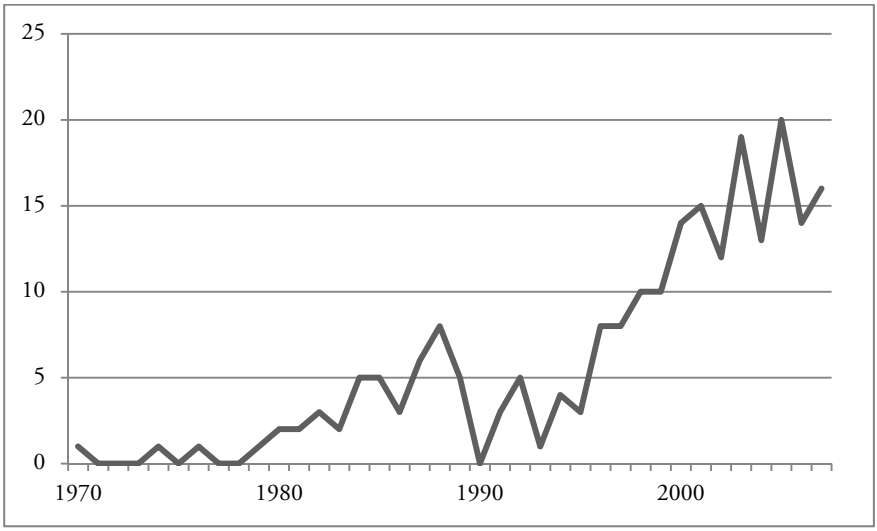


Table E.1 Distribution of 'Office machinery and computer' innovations across small, medium, and large firms, 1970-2007 (percent, period averages)

Period	Small	Medium	Large
1970-1975	15.1	24.4	60.5
1975-1982	41.9	20.3	37.8
1982-1990	50.7	28.6	20.7
1990-1994	65.9	12.5	21.6
1994-2007	78.8	9.8	11.4
1970-2007	55.9	17.7	26.4

Table E.2 Distribution of 'Radio, television, and communication equipment and apparatus' innovations across small, medium, and large firms, 1970-2007 (percent, period averages)

Period	Small	Medium	Large
1970-1975	24.2	0.0	75.8
1975-1982	21.3	8.0	70.7
1982-1990	45.9	2.8	40.2
1990-1994	32.7	2.9	44.4
1994-2007	50.5	12.9	36.6
1970-2007	41.5	7.5	48.3

Table E.3 Distribution of 'Instrument' innovations across small, medium, and large firms, 1970-2007 (percent, period averages)

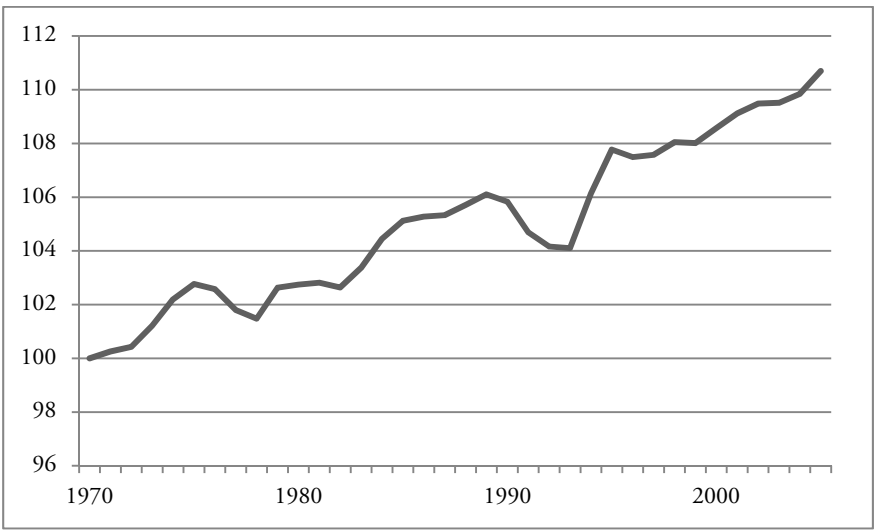
Period	Small	Medium	Large
1970-1975	35.3	18.0	46.7
1975-1982	41.6	17.0	41.5
1982-1990	61.2	14.8	24.0
1990-1994	56.9	16.6	26.5
1994-2007	76.4	10.7	13.0
1970-2007	59.4	14.1	26.5

Table E.4 Distribution of 'Computer and related activities' innovations across small, medium, and large firms, 1970-2007 (percent, period averages)

Period	Small	Medium	Large
1970-1975	16.7	0.0	16.7
1975-1982	45.8	16.7	0.0
1982-1990	69.0	12.0	7.9
1990-1994	48.0	18.0	14.0
1994-2007	77.0	10.4	12.6
1970-2007	58.9	11.6	11.0

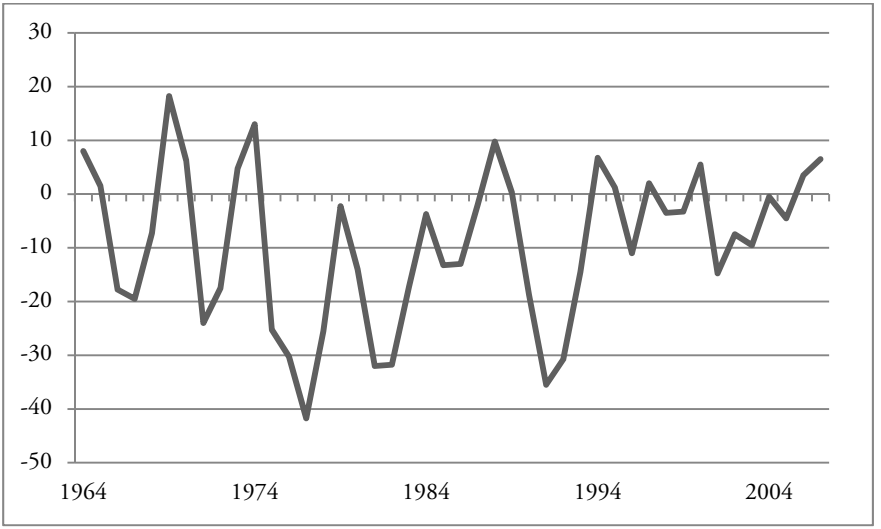
Note: The mean numbers does not add to a hundred percent until the last period due to a low number of innovations. E.g. there were only two innovations during the first period.

Figure E.6 Machinery and equipment (29) production volume, 1970=100, 1970-2007



Note: Soruce: KLEMS.

Figure E.7 General confidence indicator, 1964-2007 (annual averages)



Note: Source: Konjunkturinstitutet (National Institute of Economic Research).

Table E.5 Machinery and equipment 3 digit subgroups

SNI	Description	Innovations
29.1	Machinery for the production and use of mechanical power, except aircraft, vehicle, and cycle engines	130
29.2	Other general purpose machinery	480
29.3	Agricultural and forestry machinery	58
29.4	Machine-tools	140
29.5	Other special purpose machinery	335
29.6	Weapons and ammunition	12
29.7	Domestic appliances*	20

Note: *The number of domestic appliance innovations may be underestimated as the journals are primarily business-to-business journals.

Figure E.8 Innovations in the seven machinery and equipment sub categories, 1970-2007 (n)

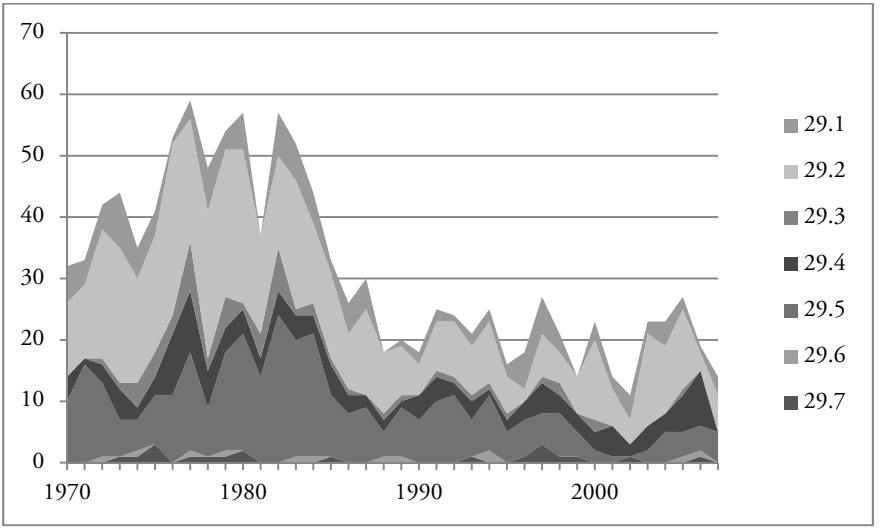


Table E.6 Distribution of 'Machinery and equipment' innovations across three digit sub groups, 1970-2007 (percent, period averages)

Period	29.1	29.2	29.3	29.4	29.5	29.6	29.7
1970-1975	14.1	44.8	4.3	7.8	26.0	0.9	2.1
1975-1982	7.5	42.6	8.4	10.6	28.4	0.4	2.1
1982-1990	10.4	38.1	4.0	10.4	35.1	1.6	0.3
1990-1994	8.2	35.1	3.4	13.0	37.9	1.6	1.0
1994-2007	15.3	38.3	2.6	18.2	21.3	1.2	3.1
1970-2007	11.9	40.1	4.1	13.3	27.6	1.1	1.9

Table E.7 Distribution of 'General purpose machinery' (29.2) innovations across small, medium, and large firms, percent (period averages)

Period	Small	Medium	Large
1970-1975	40.4	13.6	46.0
1975-1982	46.3	20.5	33.2
1982-1990	55.3	18.3	26.4
1990-1994	46.4	26.7	26.9
1994-2007	58.3	20.1	21.6
1970-2007	51.8	19.2	29.1

Table E.8 Distribution of 'Special purpose machinery' (29.5) innovations across small, medium, and large firms, percent (period averages)

Period	Small	Medium	Large
1970-1975	31.4	20.0	48.5
1975-1982	42.1	18.5	39.5
1982-1990	52.8	12.4	34.8
1990-1994	46.0	18.1	35.9
1994-2007	64.3	12.4	16.1
1970-2007	52.3	16.0	29.1

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