Master programme in Economic History

An analysis of the interaction between R&D expenditure in industry and industry growth in Sweden 1987-2007

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Abstract: This thesis disaggregates the 'Swedish paradox' with respect to Swedish manufacturing from 1987 to 2007. This is done by analyzing the impact of R&D expenditure in industry on industry growth of the manufacturing industry in Sweden from 1987 to 2007. A quantitative approach using panel-data from Statistics Sweden (SCB) and OECD is used to investigate the effect of R&D expenditure on economic growth. Through empirical analysis it is found that the effect of R&D expenditure in industry on industry growth is significant. The policy implications of this thesis suggest that investing in R&D in the manufacturing industry in Sweden might provide impetus behind growth of Swedish manufacturing in the competitive global economy of the 21st century. It is believed that this dissertation adds to academic literature on the 'Swedish paradox' by shifting analysis from the aggregate level to the meso-level/micro-level and by suggesting topics for further research.

Keywords: endogenous growth, 'Swedish paradox', panel-data analysis, Swedish manufacturing

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"economic growth springs from better recipes, not just from more cooking"

Paul M.Romer

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PREFACE

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1. INTRODUCTION

1.1 RESEARCH PROBLEM

Standing at the doorstep of a new election in Sweden, the two political blocks appear to agree on the idea that future investments in R&D are important in order to promote economic growth. The opposition headed by the Social Democrats vows to keep public R&D expenditure at 1% of GDP and views R&D expenditure as [1]*"an important factor of growth."*[2] The political block currently holding power suggests increasing R&D expenditure by spending 15 billion SEK on R&D from 2009 to 2012 in order to generate growth.[3] The idea of R&D expenditure being a factor of economic growth is also echoed at the supranational level. Cries for higher R&D expenditure in the European Union (EU) can be heard from policy-makers and bureaucrats in Brussels. The Lisbon strategy calls for higher R&D expenditure in order to reach the Barcelona target of R&D investments contributing to 3% of the GDP. Investing further in R&D is seen as a step in the direction of making the EU *"the most competitive and dynamic knowledge-based economy in the world."* [4] In academia scholars also thrive on the idea of R&D-based models of growth and endogenous growth. The past twenty years have been the heydays of endogenous growth-models in the field of the economic sciences. Influential papers by prominent scholars such as Romer (1990), Jones (1995) and Stokey (1995) emphasize the importance of technological change and R&D expenditure to generate economic growth.

The developments described above emphasizing the importance of R&D are in sharp contrast to empirical findings. Studies by scholars such as Kander and Ejermo (2006) analyze the effect of aggregate R&D expenditure on GDP growth in Sweden argue that there is an 'empirical paradox'. This paradox refers to the fact that increasing R&D expenditure does not necessarily result in GDP growth. The main body of research has to date focused on the aggregate level (macro-level) and little research has been done to analyze on the meso and

[1] My translation of "forskning är en viktig tillväxtfaktor"
[2] Swedish Social Democratic Party, 2010, Proposal for future spending on R&D by the social democratic party in Sweden accessed via www.socialdemokraterna.se/var-politik-A-till-O/utbildning
[3] Swedish government, 28/08/2008, Proposal for spending on R&D by Swedish government accessed via www.sweden.gov.se/sb/d/10405/a/109844
[4] EU, 2010, Information on the Lisbon strategy for growth and jobs from the EU accessed via http://ec.europa.eu/growthandjobs/objectives/index_en.htm

micro-level. In my opinion looking at the effect of aggregate R&D expenditure on the overall growth of the economy does not actually capture the effect of investments in R&D on economic growth. R&D expenditure at the aggregate level includes research at universities in all subjects. Some subjects given R&D funding may not yield economic growth. Some scholars also point to the links between industry and academia being rather weak. In addition to this the R&D funding given to the universities includes other costs such as the administration costs at the universities. Therefore in my opinion analyzing the aggregate level does not examine the effect of R&D expenditure on economic growth as the funds given are not only given to R&D activities.

This dissertation therefore aims to add to the current body of research by focusing on the intermediate-level and examine the empirical links between R&D expenditure and industry growth at industry-level. This thesis aims to disaggregate the 'empirical paradox' and so shed light on the effect of R&D expenditure on growth on the micro-level. To do this focus is placed on examining effect of R&D expenditure in industry on industry growth of the manufacturing sector in Sweden from 1987 to 2007.

1.2 AIM AND SCOPE

As stated above in *Section 1.1* (please see page 3), the aim of this dissertation is to provide insight on the effect of R&D expenditure in industry on industry growth of the manufacturing sector in Sweden from 1987 to 2007.

The 'empirical paradox' refers to the Swedish case. As mentioned in *Section 1.1* research to date has largely focused on the aggregate level. However, as already mentioned in *Section 1.1* a significant proportion of R&D expenditure is used to fund research at universities in all subjects (many of which does not produce knowledge which may yield economic growth) and also account for other costs such as administration costs. Examining the industry level therefore allows more targeted R&D to be studied and disaggregates the 'empirical paradox'. Examining the effect of R&D expenditure in industry on industry growth can be considered to be relevant as lot of funds is invested in R&D in Sweden. In fact of all the OECD countries Sweden invested the most in R&D in 2008.[5]

The scope of this thesis is limited to the manufacturing industry. The manufacturing industry is chosen due to its importance to the Swedish economy. Sweden is a small, export-orientated economy and is so heavily dependent on maintaining a profitable manufacturing sector. Therefore disaggregating the 'empirical paradox' with respect to the manufacturing industry allows for the findings of this dissertation to be linked to the overall performance of the Swedish economy.

Availability of data limits the scope further to 1987 to 2007. These twenty years are also interesting due to the fact that these years witnessed the rise of endogenous growth models. During this time period academia and public debates considered R&D expenditure as an elixir of economic growth. Examining these twenty years therefore allows the interaction between R&D expenditure and economic growth to be carefully studied.

[5] OECD, 2008, OECD Science, technology and industry outlook, Science and innovation country notes, Sweden accessed via http://www.oecd.org/dataoecd/18/48/41559392.pdf

1.3 OUTLINE OF THE THESIS

To provide through and coherent analysis of the impact of R&D expenditure on industry growth of the manufacturing sector in Sweden 1987-2007, this thesis is separated into seven parts.

Section 2 (page 7-19) outlines the theoretical framework for this dissertation and situates this dissertation in academic opinions of R&D based growth. To provide a backdrop for the rest of the thesis an overview of the Swedish manufacturing industry is first provided. In *Section 2.1* (page 7-12) the main traits of the Swedish manufacturing sector 1987-2007 are traced and focusing on this sector is justified. I then outline the main traits of some endogenous growth models and conclude that the effect of R&D on economic growth is uncertain. I then move onto analyzing empirical evidence by examining the major definitions of the 'Swedish paradox'. Through analysis of this empirical paradox I argue that the relationship between R&D expenditure and economic growth is uncertain and calls for further research. I maintain that by disaggregating the paradox it may be possible to shed some light on the empirical links between R&D expenditure and growth.

Section 3 (page 20-22) outlines the theoretical approach of the thesis. I briefly outline previous work done at the micro-level examining the effect of R&D expenditure on economic growth. I argue that in order to provide some insight on the interaction between R&D expenditure and economic growth a method using quantitative analysis needs to be used.

Section 4 (page 23-28) outlines the methodology used to shed light on R&D expenditure in industry on industry growth in Sweden. I maintain that the best way of approaching the research question is to use panel data using a fixed-effects model using five sub-sectors of the manufacturing sector.

Section 5 (page 29-38) of this thesis provides an overview of the data used to investigate the effect of R&D expenditure in industry on industry growth in Sweden 1987-2007.

Section 6 (page 39-46) summarizes the empirical results from the panel-data regressions and discusses the results. This section emphasizes that R&D expenditure in industry does appear to have an effect on industry growth.

Section 7 (page 47-54) concludes by stating that R&D expenditure does appear to have an effect on industry growth of the manufacturing sector in Sweden 1987-2007. Suggestions for further research are also put forward. I argue that by conducting further research on the micro-level previously unknown aspects of the 'Swedish paradox' could be uncovered.

2. BACKGROUND

2.1 MANUFACTURING IN SWEDEN

As the focus of this dissertation is on the manufacturing industry in Sweden it is important to establish some facts about the manufacturing industry. This section therefore gives an overview of the manufacturing industry in Sweden.

The manufacturing sector is important for the Swedish economy. Sweden is a small export-orientated economy and the manufacturing sector stands for roughly 1/2 of Swedish exports and 1/4 of Sweden's GDP.[6] As pointed out by scholars such as Schön (2007) the Swedish economy was originally built on a successful manufacturing sector. In an overview of Swedish industrialization Schön (2007) writes that during the 1890s transformation of the Swedish economy was achieved by changes in the structure of the manufacturing sector. The Swedish economy was therefore built on the success of a large manufacturing industry.

The composition of the Swedish manufacturing sector has changed over time. Some parts of the manufacturing industry have become redundant whilst other sectors have grown to occupy a larger value added share of the Swedish manufacturing industry. At the onset of industrialization the Swedish manufacturing sector was largely composed of heavy industries using raw materials from the natural resources in Sweden. However, in recent years there has been a shift to lighter more technical industries. In the early phases of industrialization heavy industry such as steel, paper and pulp industry were important. In more modern time there has been a movement towards more technical industry. As pointed out by Schön (2007) the 1980s witnessed the growing importance of lighter chemical industry, the pharmaceutical industry and the food, beverage and tobacco industry. During the 1980s heavy industry such as mining retreated further. Other industries such as the paper, pulp and publishing industry maintained their importance and occupied a large proportion of the value added share of total manufacturing during the 1990s and 2000s. Swedish manufacturing has therefore changed composition as heavy industries occupy a smaller

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[6] Statistics Sweden (SCB),26/08/2009 Information on Imports and Exports in Sweden – 'Export och import av varor' accessed via http://www.scb.se/Pages/PressRelease____278054.aspx

share of the value added of total manufacturing and technical industry become increasingly important.

In addition to changes in the composition of Swedish manufacturing the onset of the Third Industrial Revolution has had implications for the manufacturing industry. The Third Industrial Revolution refers to the transformation of society through the development of the microchip and ICT technology. The microchip and ICT technology has lead to the formation of new development blocks. These new development blocks provide momentum behind changes in society. For example the development of ICT technology has transformed society by reducing the barrier of distance. Through developments such as the World Wide Web borders have blurred and information which was previously difficult to come by is just a second away through the click on a screen. The development of ICT technology has lead to changes for the manufacturing industry as there is increased demand for high-technology products. Computers have therefore been given greater importance in industry and Swedish manufacturing has been pushed in a more knowledge-intensive direction. This is emphasized by scholars such as Schön (2007) who write that knowledge-intensity plays an increasingly important role in firms.[7] As there is pressure for Swedish manufacturing to remain competitive in an increasingly global political economy, innovative activities have become important for Swedish manufacturing. As pointed out by Schön (2007) one of the large changes in modern society is that the innovative process has become more structured and knowledge-intensive.[8] R&D activities have therefore grown more important to Swedish manufacturing as it needs to keep up to date with changes brought about from the Third Industrial Revolution.

The increasing importance of innovative activities has been coupled by an increased internationalization of Swedish firms. The late 1980s saw a new phase of the integration of Swedish companies into the global political economy. It is true that many Swedish companies founded during the Second Industrial Revolution in the later part of 1800s had begun internationalization before the First World War. In the interwar period Swedish companies such as Alfa-Laval, ASEA and LM Ericsson were already global as they had

[7] Lennart Schön, *En modern svensk ekonomisk historia – tillväxt och omvandling under två sekel,* (Stockholm: SNS Förlag, 2007), p.522
[8] Lennart Schön, op.cit, p.16/17

productive facilities outside Sweden. However, the late 1980s saw an increase in the rate of internationalization as Swedish companies branched out abroad. In fact from the end of the Second World War to the beginning of the 1980s Swedish foreign direct investments had been stable around 0.5-1% of GDP and in 1995 the foreign direct investments were at 5% of GDP. [9] As pointed out by Andreas Bieler (2000) the 1980s therefore saw *"an increasing transnationalisation of Swedish production."*[10] The integration of Swedish manufacturing industry into the global political economy therefore accelerated during the 1980s.

It can be argued that the internationalization of Swedish firms and increased forces of globalization has lead to some concerns for the Swedish economy. In addition to being built on a successful manufacturing industry modern Swedish society was founded on the so-called 'Swedish model'. The Swedish model is nicely summarized by Andreas Bieler (2000) as entailing *"economic policies of full employment, solidarity wages, active manpower, large public sector and generous provisions."* [11] The idea of solidarity wages might become a problem as Sweden integrates further into the global political economy. The wages of Swedish workers are higher than workers wages in some other European countries. Therefore for Swedish companies to remain operating in Sweden, Swedish manufacturing industry needs to find its strengths in order to attract capital in a world with increasingly porous borders. Forces of globalization therefore place pressure on the Swedish manufacturing industry to accommodate changes and keep up to date with a marketplace in the state of flux. Due to solidaristic wage policies it is difficult for Sweden to devalue wages to keep companies within the country. Sweden therefore needs to look for alternative ways to maintain a successful manufacturing industry. It can therefore be argued that analyzing the effect of R&D expenditure on the industry growth of the manufacturing industry is important. However, despite the concerns addressed above the Swedish manufacturing industry is still doing relatively well.

In the past twenty years the Swedish manufacturing industry has continued to grow. Lundquist et al. (2007) give a good summary of the evolution of the manufacturing sector.

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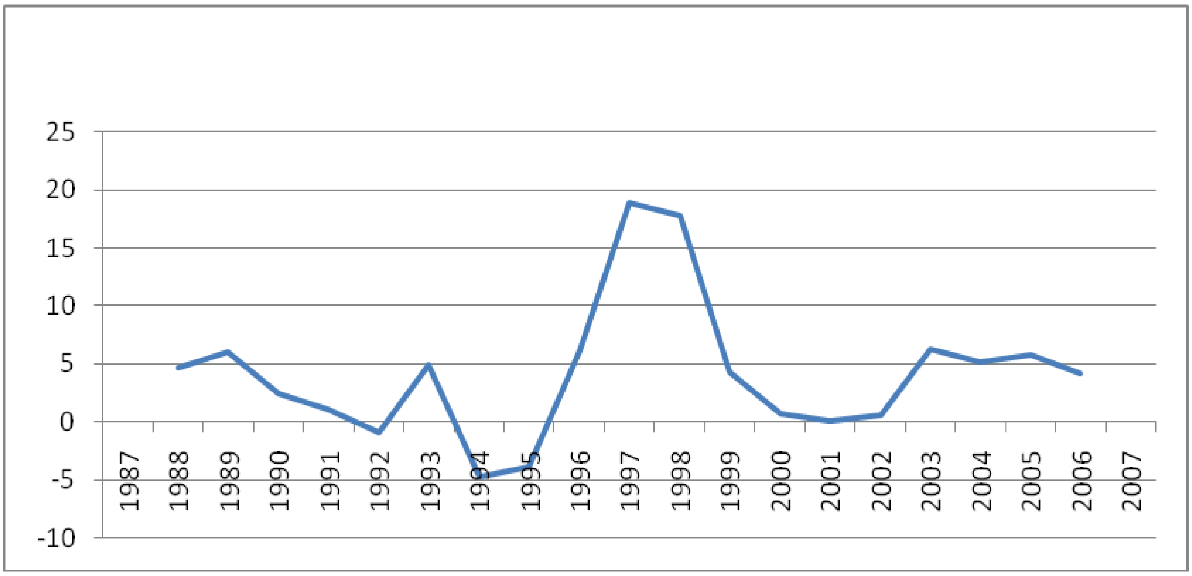
[9] Lennart Schön, op.cit. p.515

[10] Andreas Bieler, *Globalisation and Enlargement of the European Union: Austrian and Swedish social forces and the struggle over membership,* (London:Routledge, 2000), p. 47

[11] Andreas Bieler, op.cit. p.35

Lundquist et al. (2007) point to the manufacturing sector in Sweden being characterized by technological shifts. During the 1980s the growth rate of the manufacturing sector increased and was *"followed by a short crisis (1990/1993) where the last traces of the former shift were definitely faced out.* [12] The manufacturing sector continued to grow after this shift and was then *"interrupted by a downswing around the turn of the millennium."* [13]The manufacturing sector has then continued to grow with the exception of a downturn in 2005 (for graphical illustration, please see *Figure 1* below*).* The manufacturing industry has therefore continued to do relatively well for the most part of the twenty year period being considered.

***Figure 1.* Value added in manufacturing in Sweden 1987-2007. Annual percentage change. Current prices. 3 year-moving average**



Source: Statistics Sweden (SCB)

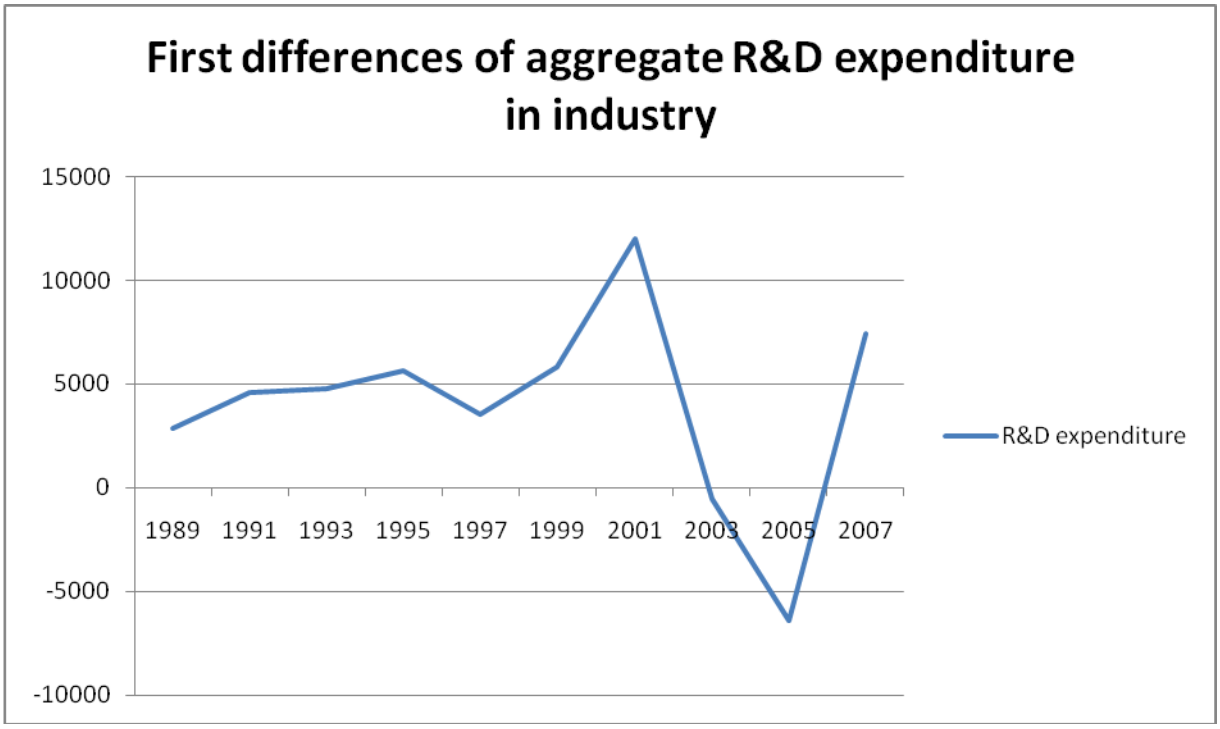
In addition to the growth of the manufacturing industry in Sweden 1987-2007 R&D expenditure in the manufacturing industry increased during this period of time. By examining *Figure 2* below (please see page 11) it is possible to see that the first differences of R&D expenditure in industry were positive for all years apart from the period 2003-2005. Therefore during the period of time considered quite a lot of funds were placed into R&D

[12] K-J Lundquist, L-O Olander & Martin Svensson-Henning, Decomposing the technology shift: Evidence from the Swedish manufacturing sector. Tijdschrift voor Economische en Sociale Geografie: Netherlands Journal of Economic and Social Geography Vol.99 (2) (2008), p.149

[13] Ibid., p.149

activities. In addition to this the amount of investment made in R&D in industry in Sweden is large in an international comparison. According to the OECD Sweden climbed from third place to become the world leader in Business Enterprise Expenditure of R&D (BERD) as a percentage of GDP from 1991 to 2003. Considering this high level R&D expenditure it therefore appears important to examine the effect of this R&D expenditure on actual industry growth.

Figure 2. ***Annual change of aggregate R&D expenditure in industry 1987-2007 in Sweden. Million SEK. Current prices.***



Source: OECD BERD database

The Swedish manufacturing industry has undergone changes in the past twenty years. The innovative process has been given more importance and has been coupled with an internationalization of companies. The onset of the Third Industrial Revolution has pushed industry in a more knowledge-intensive direction and as borders blur Sweden is left with new challenges. As Swedish manufacturing needs to remain competitive in a global market economy analyzing the effect of R&D expenditure on industry growth is highly relevant.

However, before moving onto examining the effect of R&D expenditure on industry growth it is important to consider some of the theoretical underpinnings of the relationship between R&D expenditure and industry growth.

2.2 MODELS OF ENDOGENOUS GROWTH

The idea of R&D expenditure being an ingredient of economic growth is emphasized in academia through the eyes of the endogenous growth-modelers.

The idea that R&D expenditure having an effect on economic growth can be traced back to Paul M.Romer (1990). Romer reacted against the neo-classical idea of growth being the product of labour, capital and Total Factor Productivity (TFP). According to the orthodoxy of neo-classical theories of growth, technological progress is thought of as being the only element which can bring about economic growth in the longer run. In neo-classical theories technological progress is thought of as being exogenously determined. Romer went against the neo-classical theories of growth by maintaining that growth should not be thought of as being the result of exogenous forces but that it could originate within an economic unit. Endogenous growth theory (commonly referred to as the new growth theory) therefore models technological advancement in the form of a process occurring within a country.

Romer's ideas proved to be influential and were built on by other academics. Scholars such as Grossman and Helpman (1991, 1994) and Aghion and Howitt (1992, 1998) include a R&D sector in their models of the economy. These scholars all agree on growth being driven by technological change undertaken by profit-maximizing agents. In these models performing R&D is important in order for economic growth to occur. It can be argued that the models of the endogenous growth-modelers are similar. In Romer's endogenous growth theories the economy is divided in three sectors: a final goods sector, an intermediate goods sector and a research sector. According to Romer some of the human capital is allocated to the research sector and so new ideas are generated for intermediate goods. According to Romer researchers are able to *"stand on the shoulders of giants"* [14]and so produce new ideas of higher quality. Knowledge according to Romer is therefore an accumulative process and as time passes knowledge can create snowballing effects. According to Romer these new ideas can therefore be thought of as positive spillovers from the ideas of previous researchers. Key to Romer's model is that the number of new ideas and concepts produced are in direct

[14]Joel Kurtzman, ' An interview with Paul M.Romer', *Strategy Business,* First quarter (issue 6) (1997) accessed via http://www.strategy-business.com/article/9472?gko=715e4

proportion to the amount of human capital in the research sector and to the pool of accumulated knowledge. The research sector therefore produces stocks of ideas that make the final good sector productive. The policy implication that can be drawn from Romer's work is that R&D should be subsidized as it is an important component of economic growth.

The model built by Aghion and Howitt (1992) have a lot in common with Romer's model of endogenous economic growth. Aghion and Howitt (1992) believe that there are '*quality-ladders'* and so the quality of intermediate goods improves over time making older goods obsolete. Aghion and Howitt (1992) make their model a little less stylized by arguing that R&D expenditure may generate inventions but the link of R&D expenditure to innovations is uncertain. Another model built by Grossman and Helpman (1991, 1994) examine the micro-level and the firm-level. Grossman and Helpman claim that there there are returns to R&D investments. Grossman and Helpman (1994) do acknowledge some uncertainty in the returns to R&D but they also claim that the probability of research success is proportional to the labour force employed in research laboratories. According to Grossman and Helpman economic growth is a function of the improvement of intermediate goods which improves the productivity of the final products.

At the aggregate level and the micro-level the theory of endogenous growth claims that proportionally increasing investment in R&D will proportionally increase growth. A growing stock of knowledge will according to endogenous growth-modelers generate economic growth. This idea of proportional growth has made endogenous growth-models prone to criticism from several scholars. The most severe critic has been put forward by one of the major advocates of the neo-classical theories of growth, Robert Solow. Solow (1994) argues that on the aggregate level achieving increases in rates of growth is difficult. Solow (1994) claim that levels of R&D can affect the rate of GDP growth but it may be the case that increases in levels of R&D only increases the level of GDP. This implies that R&D expenditure does not produce any long-lasting smooth growth effects but rather just a one-off increase in growth. Jones (1995) examined the idea of proportionality of the endogenous growth models empirically and reaches the conclusion that empirically there is no support for proportionality. Jones points out that according endogenous growth theories increasing the number of researchers employed within a R&D sector would increase GDP/per capita in a proportionality. Therefore in a steady-state doubling the number of researchers employed in R&D would double the GDP per capita growth. Jones (1995) points to the idea that this proportionality does not hold empirically. Jones highlights the fact that for the past forty years the number of researchers employed in R&D has increased dramatically but GDP growth has stayed more or less constant and has slightly fluctuated around a constant mean. Jones therefore concludes that the endogenous growth models are therefore inconsistent.

Jones (1995) and Solow's (1994) critique of the proportional link between growth in R&D and economic growth appears justified. Aghion and Howitt (1998) have even retreated from their previous findings and modified their original model to fit their new belief. Aghion and Howitt claim that in a steady-state increasing R&D expenditure does not necessarily increase the rate of growth. To back up this new claim Aghion and Howitt (1998) consider the role of new technologies. According to Aghion and Howitt as technologies become more complex increasing R&D is necessary in order to keep the rate of innovation constant. Therefore spillover effects of innovation show diminishing returns.

Through this brief examination of endogenous growth models it is clear that the effect of R&D on economic growth is far from certain. The proportionality of such an effect is debated both on the macro and the micro-level. Perhaps the most important lesson to be learned from this discussion is that the idea of R&D being the elixir of economic growth is an issue worth to be contemplated due to its prominence in endogenous growth theories.

2.3 THE 'SWEDISH PARADOX'

As stated in *Section 2.2* above (please see page 13-15) the theory of endogenous growth has proved to be influential despite its shaky empirical foundations. As pointed out above theories of endogenous growth encompass both the micro-level and the aggregate level (macro-level). Grossman and Helpman examine the micro-level (firm-level) and endogenous growth-modelers such as Romer examine the macro-level (aggregate level).

Through examination of the macro-level in Sweden scholars have formulated the 'Swedish paradox.' In academic literature the 'Swedish paradox' is commonly taken to have three meanings. The first meaning of the 'Swedish paradox' is by Braunerhjelm (1998) who maintains that given the high Swedish R&D investments Sweden has a small amount of high-tech exports. The second meaning of the 'Swedish paradox' is closely related to the previous formulation by Braunerhjelm but emphasizes that Sweden has a low production of high-tech products relative to high aggregate R&D expenditures (Edquist and McKelvey 1998). The third and in my opinion most interesting formulation of the 'Swedish paradox' is by Andersson et al. (2002). Andersson et al. (2002) maintain that high Swedish R&D expenditures yield little economic growth at the aggregate level. In the opinion of scholars who agree with Andersson et al. (2002) the high R&D expenditure does not produce a sufficient increase in GDP. According to Andersson et al. Sweden is therefore inefficient in transforming investments in R&D into economic growth.

The third formulation of the 'Swedish paradox' by Andersson et al. (2002) has sparked an academic debate. Commentators such Ejermo and Kander (2006) write the ideas of Andersson et al. (2002) *"just informs us that there may be some problems on the long road winding from inventive input to GDP."*[15] Ejermo and Kander (2006) proceed to examine the relationship between high-tech and low-tech sectors and compare Sweden to other OECD countries. Ejermo and Kander (2006) conclude by arguing that the returns to R&D from the high-tech and medium-tech industries in Sweden are in fact quite good. Nevertheless, in a paper in 2007 the same authors joined by Schön point to the idea of there being an empirical paradox. Ejermo, Kander and Schön (2007) point to the idea that expectations of returns to

[15] Olof Ejermo and Astrid Kander (2006) *"The Swedish Paradox"* CIRCLE Electronic Working Paper 2006/1, Lunds universitet, p.3

R&D are too high. The solution to the 'Swedish paradox' according to Ejermo, Kander and Schön (2007) is therefore simply to lower the expectations created by the endogenous growth-modelers. Ejermo, Kander and Schön (2007) maintain that policy-makers and academics lag behind empirical findings and fail to incorporate the critique of Jones (1995) and Solow (1994) in their discussions. According to Ejermo, Kander and Schön (2007) the idea that investments in R&D yielding economic growth is far from certain. In fact Ejermo, Kander and Schön (2007) argue that idea of there being a proportional effect of R&D expenditure on economic growth is in fact highly doubtful. According to Ejermo, Kander and Schön (2007) the 'Swedish paradox' is therefore best solved by simply lowering expectations and accepting the idea that R&D expenditure does not necessarily result in economic growth.

Despite the criticism put forward by Ejermo et al. (2006, 2007) little research has been done on disaggregating the empirical paradox. Research on the relationship between R&D expenditure and economic growth has focused largely on the aggregate level using nations as the unit of analysis. Ejermo and Kander (2005) do point to some problems with focusing on the aggregate level. As highlighted by Ejermo and Kander (2005) a large proportion of the aggregate R&D expenditure is given to fund research at universities. Ejermo and Kander (2005) also point to the idea that a lot of this R&D expenditure funds research performed by PhD students. Ejermo and Kander (2005) write that it is difficult to evaluate the *"performance of academia in terms of the "production of innovations."*[16] As pointed out by Ejermo and Kander (2005) the economic growth stemming from the funding placed into universities is difficult to determine. Ejermo and Kander (2005) give the example of some academics publishing an article about a new type of engine. It is true that this new type of engine could be used but its immediate economic worth is difficult to determine. In addition to this the funding given to support PhD students implies that a lot of funding is given in the form of salaries and social security cost. These reasons partly explains the fact that there does not appear to be a proportional relationship between R&D expenditure and economic growth as R&D expenditure is not placed directly into research yielding economic growth. In

[16] Olof Ejermo and Astrid Kander, "The Swedish Paradox: Myth or Reality?" in Iréne Johansson (ed.) *Uddevalla Symposium 2005 – Innovations and Entrepreneurship in Functional Regions,* (Uddevalla: Grafikerna Livréna i Kungsälv, 2006), p.405

addition to this the links between academia and industry needs to be considered. Although the World Economic Forum (WEF) points to the links between business and academia being rather strong in Sweden[17]it may well be the case that research may be performed in universities without direct links to industry resulting in inventions not being transformed into innovations. As argued by many politicians and claimed by some academics there is room for improvement in the links between academia and industry in Sweden. For example as a recent editorial points out if students leaving universities today are to prepared for an increasingly competitive labour market, industry and academia need to cooperate more closely.[18]

Another reason why aggregate R&D expenditure may not yield economic growth is that R&D expenditure is used to fund all subjects. This has the implication that aggregate R&D expenditure also funds subjects which may not yield any direct economic growth. It can be argued that investing R&D funds in research within a groundbreaking field in moral political philosophy is certainly important to better understanding of the fabric of society and human nature. However, it can be argued that such an investment is unlikely to yield any substantial economic growth. To exemplify this, a doctoral thesis giving a new interpretation and pointing to new dimensions of Jean-Jacques Rousseau's *Social Contract* may well provide a new toolbox to analyze modern society but is unlikely to result in a new innovation yielding economic growth. The suggestion put forward by the current Swedish government of increasing R&D expenditure by 15 billion SEK promises funding for all subjects.[19] This funding therefore includes subjects from the humanities which certainly are important but their propensity to yield economic growth can be debated. This is not to say that humanities are less important than subjects leading more directly to economic growth. Without the humanities and social sciences a lot of understanding of the world we live in would be lost. The fact that funding is given to all subjects therefore has the implication that some R&D

[17] Svenska Dagbladet, "Sverige mest konkurrenskraftigt i EU", *Svenska Dagbladet*, 09/05/2010, accessed via http://www.svd.se/naringsliv/nyheter/sverige-mest-konkurrenskraftigt-i-eu_4692213.svd

[18] Yngve Nygren, ' Debatt: Högskola och industri måste samarbeta bättre" *Nyteknik,* 27/04/2010 accessed http://www.nyteknik.se/asikter/debatt/article768729.ece

[19] Swedish government, 28/08/2008, Proposal for spending on R&D by Swedish government accessed via www.sweden.gov.se/sb/d/10405/a/109844

expenditure is unlikely to produce substantial economic growth. Whilst it is true that funding is not distributed equally between the subjects some funding will not generate economic growth.

Considering the links between academia and industry and R&D expenditure in academia it is not surprising that aggregate R&D expenditure may not proportionally transform into aggregate economic growth. Determining the growth stemming from academia is difficult as a lot of research is certainly beneficial for society but may not result in new innovations. In addition to this the strength of the links between academia and industry can be debated. The fact that R&D expenditure flowing into universities also include other costs such as social security costs provide some explanations as to why R&D expenditure may not generate aggregate economic growth. Therefore disaggregating the 'Swedish paradox' and examining the industry level (micro-level) instead of looking at the aggregate level allows for closer examination of the relationship between R&D expenditure and economic growth. As pointed out in *Section 3.1* (please see pages 20-21) below there has been little research on investigating the links between R&D expenditure and economic growth on the micro and meso-level. Shedding some light on the interaction between R&D expenditure in industry and industry growth therefore appears to be an issue worthy consideration.

3. THEORY

3.1 PREVIOUS RESEARCH

To date little research has been done examining the impact of R&D expenditure on economic growth on the micro-level. Nevertheless, it is possible to find some evidence by examining unpublished working papers and older articles. In this summary of previous research I conclude that the effect of R&D expenditure on the micro-level is uncertain. However, it can be concluded from previous research that R&D expenditure does appear to have a positive influence on economic growth at the micro-level. Disaggregating the 'Swedish Paradox' with respect to the industry level therefore adds to the current body of research and sheds some more light of the effect of R&D expenditure on economic growth.

In a paper from 1988 by Lars Lundberg we can find some evidence from the micro-level. Lars Lundberg examines Swedish manufacturing firms and by examining R&D expenditure in the manufacturing industry he concludes that *"the high level of R&D expenditure in Sweden, relative to competitors, improved the Swedish market position"* [20] from 1969 to 1984. However, according to Lundberg no evidence can be found for increased international specialization in R&D-intensive goods in Sweden. Lundberg examines international competiveness by an index of relative international competitiveness. Lundberg does not therefore directly examine industry growth. Nevertheless, from Lundberg's study it is possible to conclude that R&D expenditure in industry does appear to positive externalities in the manufacturing industry.

In addition to the paper by Lundberg it is possible to find some evidence by looking at the firm-level. A working paper by Daniel Wiberg (2009) examines literature on R&D expenditure, corporate governance and profitability of firms and concludes that investment in R&D is often put forward to explain persistent profits of firms above the norm. Through examination of the literature Wiberg maintains that *"not only do firms with sustained R&D investment exhibit higher profit levels, the relative level of R&D is also positively related to*

[20] Lars Lundberg (1988), "Technology, factor proportions and competitiveness", *Scandinavian journal of economics*, 90(2), p.187

the persistence of the firm's profits."[21] According to the literature review by Wiberg, increasing R&D expenditure does have a positive influence on growth. Another working paper by Johansson and Lööf (2008) argues that at the firm level R&D strategy has an impact on the profitability of firms. By examining 1767 randomly selected manufacturing firms in Sweden and conducting econometric analysis Johansson and Lööf find that persistent R&D expenditure has a positive and statistically significant effect on profits. These two papers examining the firm-level therefore point to the idea that R&D expenditure in firms has a positive effect on profits. However, from these studies it is not possible to conclude anything about the proportionality between R&D expenditure and growth of firms. It is therefore difficult to conclude anything about the size of the effect of investments of R&D on growth of the firms from these studies.

From the summary of the literature above it is possible to conclude that that R&D expenditure has a positive effect of growth at the firm-level. However, this effect is difficult to quantify. From the studies by Wiberg (2009) and Johansson and Lööf (2008) it is only possible conclude that the effect of R&D expenditure on the profits of the firms is positive. It therefore appears as if the effect of R&D expenditure on economic growth on the micro-level is uncertain. This uncertainty regarding the returns to R&D expenditure can also be seen by examining the opinions of editorials in academic journals. For example in an editorial from 1994 in *Chemical Week* it is apparent that firms face a tradeoff between investing in R&D and making a larger profit or making an investment in another form. David Rotman (1994) writes that some top executives of the U.S. chemical industry are wondering *"where's the payoff?"*[22] of the high investments made in R&D. There appears to be uncertainty of the returns to R&D investments both at the micro-level and at the aggregate level. Examining the interaction between R&D expenditure in industry and industry growth therefore appears to be worth some consideration.

[21] Daniel Wiberg (2009), R&D, Corporate Governance and profitability of firms – A lit review, *CESIS Working* Paper, p.17

[22] David Rotman, 'From pain to payoff', *Chemical Week,* 154 (1994), p. 9

3.2 THEORETICAL APPROACH OF THIS THESIS

Examining industry-level therefore allows for the links between R&D expenditure in industry growth to be closely studied. In addition to this analyzing the empirical links between R&D expenditure in industry and industry growth sheds some light on another dimension of the 'Swedish paradox'.

In order to provide coherent analysis a good methodology needs to be employed. Some of the previous research highlighted above (for example the literature review written by Wiberg) is qualitative in nature. However, in order to understand the empirical links between R&D expenditure and industry growth I believe employing a quantitative method is better suited. Using an econometric method paves the way for a robust answer to the research question and allows for the idea of proportionality to be more carefully studied. As will be developed in *Section 4.1* (please see pages 23-27) I believe that panel-data analysis using a fixed-effects model is the best method to use to examine the influence of R&D expenditure on industry growth.

4. METHODS

4.1 THE MODEL

In order to provide a good analytical answer to my research question it is important to make use of a coherent methodology. As stated above in Section *3.2* (please see page 22) I believe that a quantitative method ought to be used when studying the empirical links between R&D expenditure in industry and industry growth. In this section I give details on the method I intend to use to give insight on the impact of R&D expenditure in industry on industry growth in Sweden from 1987 to 2007.

As pointed out in *Section 3.2* (please see page 22) I need to make use of econometric techniques in order to provide a robust answer to my research question. The time period I'm considering spans twenty years and due to data limitations I only have data for odd years (1987, 1989…2007) for R&D expenditure in industry. An overview of the data is provided in *Section 5.1* (please see page 29-33). This gives me with just 11 observations for R&D expenditure in industry in Sweden. It is therefore difficult to use aggregate-level data to shed light on how R&D expenditure in industry influences industry growth. The time-period which I'm considering is too short to obtain valid regression results. The solution to this problem is to use panel-data analysis. In order to conduct a panel-data analysis I can make use of data collected by OECD and Statistics Sweden (SCB) (for a discussion on the data used please see *Section 5.1*).

Panel-data regression is a way of pooling data and allows for analysis of data in several different dimensions. As pointed out by Marno Veerbek (2008) using panel data has several advantages as *"the availability of repeated observations on the same units allows economists to specify and estimate more complicated and more realistic models than a single cross-section or a single time series would do."* [23] In addition to this as pointed out by Veerbek *"estimators based on panel data are quite often more accurate than from other sources"*[24] as data varies over two dimensions (individuals and time). Using panel-data therefore solves the problem of a rather small data pool and is therefore the best suited econometric

[23] Marno Verbeek, *A guide to modern Econometrics,* (West Sussex: John Wiley&Sons, 2008), p.355
[24] Marno Veerbek,, op.cit., p.357

techniques to give insight of R&D expenditure in industry growth in Sweden. Panel-data analysis can be broadly classified into two broad categories: fixed-effects and random-effects model. A fixed-effects model is a linear regression model in which the intercept varies over individual units. In fixed-effects models each unit is given a separate intercept functioning as a dummy variable. A random-effects model is different to a fixed-effects model as it does not assume individual effects. As stated by Verbeek (2008) a fixed-effects model is recommended when the t is large the number of i is relatively small (the time dimension is larger than the cross-sectional dimension). In a fixed-effects model omitted variables that differ between cases but are constant over time are therefore controlled for. As I only have 11 observations for R&D expenditure it appears as if I need to make use of a fixed-effect model to perform the panel-regression of R&D expenditure in industry on industry growth.

However, using panel-data analysis means that I have to make some decisions regarding which industries to include in my regressions. Data is missing for some years for several of the industries. In order for my panel-data regressions to provide some insight of the impact of R&D expenditure on the growth of the manufacturing industry I need to choose different parts of the manufacturing industry. From these different parts of the manufacturing sector I need to be able to generalize and give some insight on the impact of R&D expenditure in industry on industry growth for the entire manufacturing sector. In addition to this I want my estimators to be as a robust as possible and therefore it would be an advantage if I could obtain a balanced panel[25] for my regressions.

To choose which industries to use I begin by examining the data available. It is noted that in many industries a lot of data is missing. However, for five industries data for every year is available. I also want these industries to represent different parts of the manufacturing industry so that I can generalize the regression results to represent manufacturing in Sweden. To make sure the industries represent manufacturing in Sweden I use the EU Industrial Scoreboard.[26] The EU Industrial Scoreboard classifies industries into three broad

[25] A panel is referred to as being 'balanced' when there are no observations missing.
[26] EU, 2009, the 2009 EU industrial R&D investment scoreboard accessed via http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm

bands: low R&D intensity, medium R&D intensity and high R&D intensity. Choosing one sub-sector from each band provides me with a good balance of industries as they allow me to obtain a more holistic view of the manufacturing sector.

The following industries appear to be a good choice. The sub-sector of Chemical products (including pharmaceuticals) is classified at the higher end of the spectrum. Food, beverages and tobacco is located towards the medium end of the R&D intensity spectrum. The industry of pulp, paper, paper products, printing and publishing is located towards the low-medium end of the R&D intensity spectrum. Textiles, textile products, leather and footwear is not classified by the EU industrial scoreboard but as it makes the dataset larger it is included in the regressions. There is also complete data for Furniture and other. It is difficult to classify this industry according to the EU Industrial Scoreboard as 'other' is undefined. Nevertheless, as there is data available for every year the industry is included to yield a larger dataset. In addition to this these five sectors are relatively large and contribute to a large share of the value added of the entire manufacturing industry (for graphical representation, please see *Figure 3* on page 26*). Section 2.1* (please see page 7-12) providing an overview of Swedish manufacturing points to the fact that industries such as the food, beverage and tobacco industry and the chemical industry also became increasingly important to the Swedish economy during the time period considered. These industries therefore contributed to a large value added share relative to total manufacturing in Sweden.

Therefore using these five sub-sectors of the manufacturing industry therefore appear to be my best choice and provide me with enough degrees of freedom to run a panel regression.

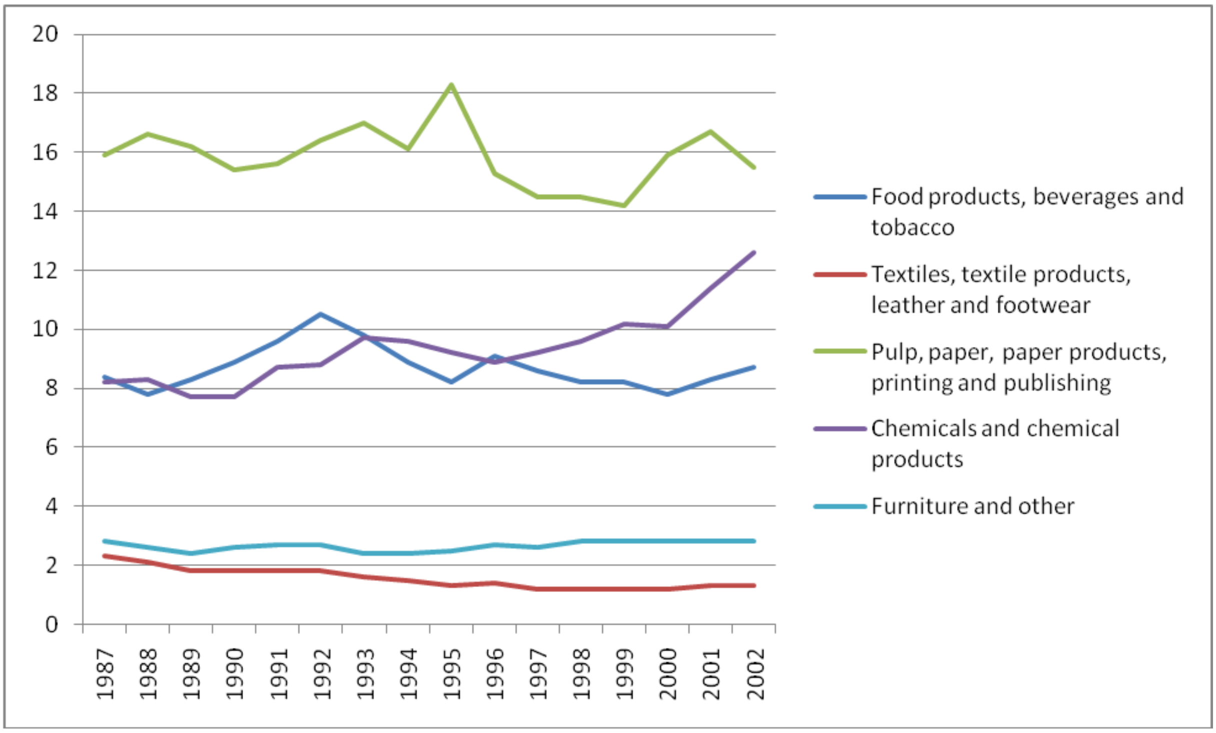
1. Chemicals and chemical products (including pharmaceuticals)
2. Food, beverages and tobacco.
3. Pulp, paper, paper products, printing and publishing
4. Textiles, textile products, leather and footwear [27]
5. Furniture and other

[27] When collecting the data from OECD and Statistics Sweden (SCB) the data for this variable is available under the classification 'textiles, fur and leather'. For discussion of the variables please see *Section 5* (pages 28-32)

In addition to this I believe that the results I obtain from my regressions can be generalized to give an idea of the impact of R&D expenditure in industry on the growth of the manufacturing sector from 1987 to 2007. The five sub-sectors represent different parts of the manufacturing industry and occupy a high value added share relative to total manufacturing.

<u>Figure 3.</u> Value added shares relative to total manufacturing in Sweden 1987-2002.

Value added shares relative to total manufacturing in Sweden 1987-2002 in %.



Source: OECD STAN indicators database

As already mentioned to run my regression model I need to use a model using the 'fixed-effects' specialization. As already mentioned panel-data analysis is a way of pooling cross-sectional data and longitudinal data for different units of analysis. Using panel-data is therefore a way to overcome problems of too short time-series and not enough units for cross-sectional analysis. Therefore for the purpose of this thesis:

i= sector 1,.., sector 3 (cross-sectional dimension)

t= 1987,…, 2007 (time-dimension)

It is true however, that to analyze the effect of R&D expenditure on industry growth I do need to make use of some control variables. I examine the control variables used in *Section 4.2* (please see page 28) below.

4.2 VARIABLES NEEDED FOR MODEL

Having outlined above the econometric technique I intend to use I will now move onto considering the variables I need to use. R&D expenditure in industry is a relatively straightforward variable and details on the data collected for this variable are given in *Section 5.1* (please see pages 28-32). The best estimate of industry growth to use is value added and data on this variable is also readily accessible and discussed in detail in *Section 5.1*.

In addition to R&D expenditure in industry and value added I need to make use some control variables. Whilst it is true as pointed out above in *Section 4.1* (please see page 23-27) that fixed-effects panel data regressions partly controls for omitted variable bias I still need to control for some variables. It is well-known that labour and capital play a role in economic growth at industry level. In addition to this labour and capital play a role in the neo-classical theories of growth. Using these two variables as controlled variables therefore appears to be a good choice.

A thorough discussion of these variables and the data collected for them is available in the next section (*Section 5.1).*

5. DATA

5.1 SOURCE MATERIAL

As stated in *Section 4.2* above (please see page 28) data for number variables is needed in order to investigate the effect of R&D expenditure in industry on industry growth in Sweden from 1987 to 2007. This section outlines the data collected and emphasizes that whilst the data collected can be used to shed some light on the effect of R&D expenditure in industry on industry growth the results obtained from the regressions cannot be considered as being definite.

As already mentioned the following variables are needed in order to run the panel-data regressions using the 'fixed-effects' specification.

Dependent variable:

- Value Added for five sub-sectors of the manufacturing industry per year.

Explanatory variables:

- R&D expenditure in industry for five sub-sectors of the manufacturing industry per year (variable of interest)
- Investment in industry for the five sub-sectors of the manufacturing industry per year (controlled variable)
- Labour (number of people employed) in a given year (controlled variable)

Data is collected from several different sources and for analysis to be coherent these sources need to be examined. I will therefore examine each variable separately and point to some problems with the data collected.

1. **Dependent variable: Value Added (Industry Growth)**

To measure industry growth, the Value Added of the five sub-sectors of the manufacturing industry is used. To my knowledge, data on Value Added for the five sub-sectors is not readily available from a single data source. However, the data is annually collected by Statistics Sweden (SCB) for the national accounts but Statistics Sweden does not publish this data so it is accessible by a student In addition to this Statistics Sweden has modified its classification on industries (SNI codes) for the years of interest. Statistics Sweden classified industries according to the SNI 1992 code until 2002 and then started to make use of the SNI 2002 code. However, to perform the regressions for this study the SNI codes are carefully looked at and the best is done to ensure that the data is comparable. It is important note that as the SNI codes are not kept the same the results of the regressions need to be interpreted with some caution and cannot be considered as being definitive. The SNI codes used are as follows: Food beverages and tobacco (SNI92=15+16 and SNI02=SNI 15+16), textiles, fur and leather (SNI92=SNI 17+18 and SNI02=SNI 17+18+19), furniture and other manufacturing (SNI92= SNI 36, SNI02=SNI 36), chemicals and chemical products (SNI 92= 24 and SNI02=SNI 24) and paper, pulp and publishing (SNI92=SNI 21+22 and SNI02=21+22). To complicate things further the data is not stored by the SCB in one database. The database is therefore collected from a database supplied by the OECD from 1987 to 1994.The data from 1995 is collected from the 1995 Statistical Yearbook available online. [28] The data from 1997 to 2007 is published by SCB online in two different databases. [29] The data is available in millions of SEK at current prices. [30]

This data is not perfect. Although a lot of effort has gone into ensuring that the data is comparable for the entire 20 year time period there may well be deviations for year to year. Nevertheless, the data collected is from a reliable source (Statistics Sweden) and is the best data I can find to perform this study.

[28] Statistics Sweden (SCB), National Accounts Sweden from Statistics Sweden (SCB) accessed via http://www.scb.se/Pages/Product____30923.aspx

[29] Statistics Sweden (SCB), data for 1997-2002 accessed via http://www.ssd.scb.se/databaser/makro/SubTable.asp?yp=tansss&xu=C9233001&omradekod=NV&huvudtabell=BasfaktaForetag&omradetext=Näringsverksamhet&tabelltext=Basfakta+f%F6retag+enligt+F%F6retagsstatistiken+efter+n%E4ringsgren+SNI92%2E+%C5r&preskat=O&prodid=NV0109&starttid=1997&stopptid=2002&Fromwhere=M&lang=1&langdb=1

Statistics Sweden (SCB), data for 2003-2007 accessed via http://www.ssd.scb.se/databaser/makro/SubTable.asp?yp=tansss&xu=C9233001&omradekod=NV&huvudtabell=BasfaktaFEngs&omradetext=Näringsverksamhet&tabelltext=Basfakta+f%F6retag+enligt+F%F6retagens+ekonomi+efter+n%E4ringsgren+SNI+2002%2E+%C5r&preskat=O&prodid=NV0109&starttid=2003&stopptid=2007&Fromwhere=M&lang=1&langdb=1

[30] It is true that due to inflation and other trends it would be better to use constant prices but as this data is not readily available for all years using the sources listed, current prices are used instead.

2. Variable of interest: R&D expenditure in industry

Data for R&D expenditure in industry is collected every other year (1987,1989…2007) by Statistics Sweden (SCB). However, this data is not stored by Statistics Sweden online and so OECD is used to access the data. The data from OECD is published under the name BERD (Business Intramural R&D expenditure) and consists of both R&D expenditure by individual companies and funds given from the government. The R&D statistics cover: private and public manufacturing enterprises, private and public R&D institutes serving industries, commercial R&D companies serving manufacturing companies and business service companies.

The data is compiled by mailing mandatory questionnaires to all enterprises with more than 50 employees having reported annual R&D expenditures according to previous financial statistics and R&D surveys. Some information on R&D expenditure of firms with 20-49 employees is also drawn from their annual reports submitted to the Patents and Registrations Office. The questionnaire is also sent to private and public institutes serving industry (units believed to perform or finance R&D activities) and commercial R&D companies. The reporting unit is therefore the enterprise or institute. It can be argued that the fact the reporting unit is the enterprise or institute is problematic as the reporting enterprise or institute does have some room to maneuver and can report a false figure. The reports therefore rely on the honesty of the reporting enterprise or institute. In addition to this the data does not regularly include SMEs with fewer than 50 employees and according to the OECD *"ad hoc surveys of these enterprises show that a significant amount of R&D is performed there, especially among consultancy firms and spin-off companies."* [31] This data is therefore not perfect but it is the best I can find for the purpose of this study. The data is available in millions of SEK at current prices.

The ISIC-related Swedish Standard Classification of all Economic Activities for enterprises is used and the best is done to ensure that the ISIC-codes are the same as the SNI-codes described above. The ISIC-codes for the industries used are as follows food beverages and

[31] OECD, Research and Development in Industry accessed via OECDSource

tobacco (ISIC Revision 3= 15+16), textiles, fur and leather (ISIC Revision 3=17+18+19), furniture and other manufacturing (ISIC Revision 3=36), chemicals and chemical products (ISIC Revision 3= 24) and paper, pulp, printing and publishing (ISIC Revision 3= 21+22). Although effort is made to ensure that the data is comparable it is worth to reiterate that the results from the regressions needs be interpreted with some caution. The data is not perfect but it is judged to be good enough to shed some light on the effect of R&D expenditure in industry on industry growth in Sweden from 1987 to 2007.

3. Control variable: Investment in industry

As was argued in *Section 4.2* (please see page 28) I need to make use of control variable. I need to control for capital. As data on capital is not available for the whole time period I will use investment instead. The data available for investment includes physical investment such as land and machinery and excludes investments made in R&D. Including this variable in the regressions allows me to control for industries that makes a lot of other investment (for example in machinery and land) but little investments in R&D.

Data on investment is available from the Swedish National Accounts via the Statistical Yearbook.[32] The data is collected by sending a mandatory report to large Swedish and by using the Swedish tax registers to obtain data for the investment made by smaller firms. According to Statistics Sweden (SCB) a reliable estimate of the investments made by industry is therefore obtained. This data is available in millions of SEK at current prices.

Although the data on investment is obtained from administrative records it cannot be thought of as being completely reliable. This data suffers from the same problems as the data on the value added of industry as the SNI classification codes has changed over time. To tackle this problem every effort is done to ensure that the data over time is comparable but there may well be some discrepancies. The SNI classification codes for the data on investment is the same as the data for value added in industry (please see page 29-30)

[32] Statistics Sweden (SCB), National Accounts Sweden from Statistics Sweden SCB, 'Statisitk Årsbok' accessed via http://www.scb.se/Pages/Product____30923.aspx

4. **Control variable: Labour in industry**

As argued in *Section 4.2* (please see page 28) I also believe I need to control for the amount of labour in an industry. The idea of controlling for labour links back to endogenous growth theories and the Solow growth model which emphasize the importance of labour for economic growth.

Data on the amount of labour in industry is collected from the Swedish National Accounts via the Statistical Yearbook. As the data of hours worked per year is not available for the whole 20 year period I use the number of people employed in a certain industry. Using the number of people employed instead of hours worked is not unproblematic. The number of people employed includes both full-time and part-time employees. This is a problem as increasing the number of part-time employees might not yield as much economic growth as increasing the number of full-time employees. However, given data limitations this is the best data available to me.

Again although this data is collected from administrative records it has the same Achilles heel as the rest of the data collected for this study: the SNI codes for time period being considered have not been kept the same. Again the SNI code classification is carefully studied to make the data as comparable as possible but caution needs to be taken when considering the results from the regression analysis.

Having carefully gone through the data sources it is time to turn to the results of the regression analysis.

5.2 METHODOLOGICAL CONSIDERATIONS

As pointed out in *Section 4* .1(please see page 23-27) panel-data is suitable for the purpose of this study. Panel-data controls for omitted variable bias and allows for heterogeneity between panels. However, using panel-data does call for some methodological considerations to be addressed. This section discusses the major traits of the dataset and highlights how problems regarding panel-data are addressed.

This section is split in eight parts. The first part emphasizes the advantage of using a balanced panel. The second part points to some techniques used to simplify the interpretation of the co-efficients of the regressions. The third part summarizes the Hausman test undertaken. The fourth part discusses stationarity. The fifth and sixth part considers heterogeneity and autocorrelation. Part seven emphasizes that the sample is normally distributed. The final part discusses the use of controlled variables when examining the relationship between R&D expenditure in industry and industry growth.

1. BALANCED PANEL

As already pointed out in *Section 4.1* (please see page 23-27) the dataset used for this study is balanced. The fact that the dataset is balanced implies that there are no observations missing for the entire dataset. The number of observations for each industry is the same (11 for each industry). The advantage of using a balanced panel is that there is no missing data and so the results obtained from the regressions can therefore be thought of as being representative of the entire dataset. As argued in *Section 4.1* (please see pages 23-27) the industries used are believed to be representative of Swedish manufacturing. The results from the balanced panel therefore give insight on the effect of R&D expenditure in industry on industry growth of the manufacturing industry from 1987 to 2007. As also pointed out in *Section 4.1* emphasis was placed on obtaining a balanced panel at the cost of a slightly smaller dataset. Nevertheless, this small dataset does provide enough degrees of freedom to run the 'fixed-effects' regression. If an unbalanced pool was to be used the data set would be very incomplete. For many variables there were more than half the observations missing. Therefore using a slightly smaller dataset with complete representation is preferred for the purpose of this study.

2. SIMPLIFYING THE INTERPRETATION OF THE CO-EFFICIENTS FROM THE REGRESSIONS

In order to examine the effect of R&D expenditure in industry on industry growth the results from the regressions need to be relatively easy to interpret. The regressions are easier to make sense of if the metrics of the explanatory variable is comparable with the metrics of the dependent variable. For the purpose of this study the natural logarithms (ln) are taken of both R&D expenditure in industry and the value added of the industry. Taking the natural logarithms enable easy interpretation of the co-efficients as changes are in percent (%). As pointed out by an econometrics textbook when *"both the dependent variable and independent variable(s) are log-transformed variables, the relationship is commonly referred to as elastic in econometrics"* and so in *"a regression setting, we'd interpret the elasticity as the percent change*." [33] Taking the natural logarithms therefore allows for the effect of the explanatory variables on the dependent variable to be readily discussed.

3. A 'FIXED EFFECTS' VERSUS 'RANDOM EFFECTS' MODEL

As already discussed in *Section 4.1* (please see pages 23-27) a 'fixed-effects' model is believed to be the most suitable to tackle the research question. To make sure that a 'fixed-effects' model is most suitable to tackle the research question, a Hausman test is performed. A Hausman test (1978) is used to test if the random-effects estimator is unbiased (the error term u_{it} is uncorrelated with the explanatory variables).

Ho: $E(u_{it}|X_{it})=0$

H_1: $E(u_{it}|X_{it}) \neq 0$

If the null is rejected, the random-effects estimator cannot be used. Rejecting the null therefore implies that a 'fixed-effects' estimator is preferred.

[33] UCLA, Website containing information about econometrics from UCLA accessed via http://www.ats.ucla.edu/stat/SAS/faq/sas_interpret_log.htm

Running a Hausman test on the dataset used in this study confirms that a 'fixed-effects' estimator should be used as the null hypothesis can be rejected at the 2% level. This confirms the idea that a 'fixed-effects' model is indeed suitable for the dataset used in this study.

4. STATIONARITY

Another condition that needs to be considered is stationarity. In order for the regressions to be valid the variables need to be stationary. Stationary variables imply that the variables aren't trending and so inference can be made from the regressions. Using stationary variables is therefore necessary in order to determine the effect of one variable on another.

A way to test for stationary is to use unit-root test. For the purpose of panel-data a Levin, Lin and Chu (2002) panel unit root rest is used. If the null hypothesis of a Levin, Lin and Chu (2002) test cannot be rejected, all individuals contain a unit root. If the null hypothesis can be rejected all individual series are stationary. Running a Levin, Lin and Chu (2002) unit root test reveals that the variables are indeed stationary as the null can be rejected at the 1% level. The result of the Levin, Lin and Chu (2002) is shown in the appendix (please see pages 59-62).

5. HETEROSKEDASTICITY

The Classical Linear Regression Model (CLRM) is based on a number of assumptions concerning disturbances. When using panel-data two of these assumptions need to be considered. Firstly, heteroskedasticity needs to be considered. In the CLRM model the variance of the error term is constant for all *i*:

$V(u_t)$=sigma^2

When the variance is not constant this assumption is violated. The violation of this assumption is known as heteroskedascitiy. Heteroskedascity implies that the conditional distribution of each level of R&D expenditure in industry corresponding to a given value added value does not have the same variance. Heteroskedascitiy is common in cross-sectional data as the industries included in this study are of different sizes and value added levels perhaps resulting in scale effects being present. To test for heteroskedascticity a

Breusch-Pagan test can be used. The null hypothesis of the Breusch-Pagan test states that the variance of the error term is zero. If the variance of the error term is zero there are no random effects. However, the Breusch-Pagan test is not supported by the software used for this thesis (Eviews). Instead the Eviews manual recommends using a 'coefficient covariance method' to deal with the problem of heteroskedatisicty. [34] For the purpose of this study is assumed that by using the 'coefficient covariance method' the problem of heteroskedaticity is dealt with and inference can therefore be made from the results.

6. AUTOCORRELATION

The second CLRM assumption which needs to be considered is the idea of autocorrelation between the error terms u_i and u_j.

$Cov(u_i, u_j) = 0$ for all $i \neq j$

The violation of this assumption implies that there is a relation between the error term in the time period t and in the previous period (t-1). Autocorrelation is therefore present. For the purpose of this study autocorrelation implies that the disturbance term related to time t in a specific industry is not related to any other year's disturbance term for the same industry. To test for autocorrelation a Durbin-Watson test is performed.

A Durbin-Watson statistic lies between zero and four (value zero and four correspond perfect correlation, two corresponds to no autocorrelation). A number of critical values for the d-statistic are recommended for determining whether there is autocorrelation. For the purpose of this study it appears as if autocorrelation is present in the sample as the d-statistic does not lie within the acceptable range of the d-statistic. To correct this complication GLS is used and the data program is modified by adjusting the standard errors using 'cross-section weights'. By performing these changes the problem of autocorrelation is dealt with and inference can be made from the regressions.

7. NORMALITY

As the sample used for this study is relatively small (55 observations for R&D expenditure in industry and 55 observations for value added of industry) the normality of the error terms

[34] Eviews (Quantitative Micro Software) (2007),*Eviews manual for Eviews version 6*, p.485

needs to be considered. The error terms should be normally distributed with a mean of zero and a variance sigma^.[35] This idea of normality is important as it is necessary in order to make correct inference.

To test for normality, the Jarque-Bera test is used. The Jarque-Bera test controls for skewness (the symmetric distribution around the mean value and kurtosis (the size of the tails). In a normal distribution the residuals are perfectly distributed around the mean and have a kurtosis of three and the Jarque-Bera value is close to zero. Performing the Jarque-Bera test confirms that the sample is within the range permitted of the Jarque-Bera statistic. This implies that inference can be made from the regressions in this study.

8. CONTROL VARIABLES

Finally, the idea of using controlled variables needs to be considered. In a linear OLS regression controlled variables need to be used since when running the regression only one panel is considered. However, an advantage of using panel-data is that omitted variables that differ between the cases but are constant over time are controlled for. The aim of this study is to examine on the effect of R&D expenditure in industry on industry growth. Nevertheless, variables which are not constant over time need to be included in the regressions.

It is true that many variables affect the value added of an industry. The more variables included the more the chance that the residual is indeed white noise. At the same time including more variables will increase the adjusted R^2 even though they are not important. This gives a false picture of how good the fit of the explanatory variables are. Therefore only the controlled variables which are believed to be most important are included. In my opinion these are capital and labour. Capital and labour plays a role in many theories of economic growth such as the Solow growth model. Regressions are therefore run using R&D expenditure in industry, capital in industry and labour in industry.

[35] Damodar Gujararti, *Essentials of Econometrics*, (New York: McGraw-Hill,2006), p.213

6. EMPIRICAL ANALYSIS

6.1 EMPIRICAL RESULTS

Having carefully gone through the methodological considerations and analyzed the data collected a regression model is estimated using the following variables:

- Value added in industry (in millions SEK current prices per year)
- Level of investment (capital) in industry (in millions SEK current prices per year)
- Labour in industry (number of people employed in millions)
- R&D expenditure in industry (in millions SEK current prices per year)

To decide the form of the regressions the idea of multicollinearity is considered. Industries tend to spend similar amounts on R&D from year to year. The idea of multicollinearity is therefore needs to be considered if lagged variables of R&D expenditure in industry are to be inserted into the same regression. Multicollinearity arises when two or more explanatory variables in a regression are highly correlated. Multicollinearity implies that co-efficient estimates may be highly responsive to small changes in the data. The presence of multicollinearity leads to larger standard errors and resulting in a smaller t-statistic.[36] The presence of multicollinearity therefore leads to difficulty in interpreting individual regression parameters resulting in difficulty in making correct inference. A high R^2 and few significant t-ratios are signs of multicollinearity. Running a regression using lagged variables of R&D expenditure in industry as explanatory variables display these warning signs of multicollinearity. The standard errors are very large and the t-statistics are small. As *Section 5.2* (please see pages 34-38) tested for the presence of a unit-root it can be concluded that these few significant t-values and high R^2 values are not the result of a common trend. However, this problem is not surprising as I only have observations for 11 years for each variable ranging a period of 20 years. The construction of correlation matrices for each panel also reveals some high levels of correlation between lagged variables of R&D expenditure for some of the panels (the correlation matrices are displayed in the Appendix).

[36]Damodar Gujararti, *Essentials of Econometrics*, (New York: McGraw-Hill,2006), p.366

Therefore to avoid a high degree of multicollinearity several different regressions are run using one lagged variable of R&D expenditure in industry at a time.

Regressions are therefore run in the following form.

$$\ln(growth_{it}) = \beta_1 + \beta_2 \ln(RD\exp_{it-k}) + \beta_3 \ln(investment_{it}) + \beta_4 \ln(labour_{it}) + \varepsilon_{it}$$

Where $\varepsilon_{it} = \lambda_i + v_{it}$

Growth = Value Added of industry

RDexp= R&D expenditure in industry (t-k specifies the lag of the variable)

Investment= level of investment (capital)

Labour = number of people employed in an industry

As pointed out in *Section 4.1* (please see pages 23-27) due to data availability I only have statistics for every other year for R&D expenditure in industry (1987, 1989,...,2007) and so the lags on R&D expenditure are therefore only for even years (-2, -4 etc). If a regression includes a lagged variable of RDexp not statistically significant at the 10% level it is not displayed in *Table 1* (please see page 41) below and not discussed in this dissertation.

The regressions are run using the model specifications discussed in *Section 4* (please see page 23-28) and the results are summarized in *Table 1* below. The level of statistical significance is indicated using the notation specified below the table.

Table 1 **Table showing the results from the GLS 'Fixed Effects model' using ln(valueadded) as dependent variable**

Variable	Regression 1	Regression 2	Regression 3
C	3.39****	6.12****	6.23****
ln(RDexp)	0.25***		
ln(RDexp)-2		0.16*	
ln(RDexp)-4			0.17***
ln(investment)	0.50****	0.30****	0.30***
ln(labour)	-0.26****	-0.10****	-0.05*
Adjusted R^2	0.95	0.97	0.97
N	55	50	45

**** = statistically significant at the 1% level

***=statistically significant at the 2% level

**= statistically significant at the 5% level

*= statistically significant at the 10% level

The results summarized in *Table 1* reveal the following results. The co-efficient for R&D expenditure in industry is positive for all three regressions. The co-efficient for the level of investments is positive for all three regressions. The co-efficient for labour (number of people employed in industry) is negative in all three regressions. The fact that this co-efficient is negative is peculiar. However, as the point of this dissertation is to look at the impact of R&D expenditure in industry on industry growth this co-efficient is not analyzed in detail.[37] The co-efficients is the largest at time t (ln(RDexp)) when increasing R&D expenditure in industry by 1% will yield a 0.25% increase in value added of the industry. With a two-year lag (a one year lag is not possible due to data availability) the effect is statistically significant at the 10% level and is relatively large and positive. A 1% increase in R&D expenditure will yield a 0.16% increase in value added. With a four-year lag (again a three year lag is not possible due to data availability) the co-efficient on RDexp is similar to the co-efficient on the two-year lag. A 1% increase in R&D expenditure yields a 0.17% increase in value added in industry. This co-efficient is statistically significant at 2% level. The effect of the two lags therefore appears to be similar (0.16 respective 0.17).

The adjusted R^2 value is very high for these three regressions (0.95, 0.97 and 0.97 respectively). The fact that these adjusted R^2 are so high would normally cause some skepticism. However, as the data was carefully analyzed in both the overview of the data provided in *Section 5.1* (please see page 29-33) and in the methodological considerations part in *Section 5.2* (please see page 34-38) these regressions are taken as being valid to shed some light on the effect of R&D expenditure in industry on industry growth.

The number of observations ranges between 55 and 45 which is a relatively small sample. However, as the data was carefully analyzed in *Section 5.1* (please see pages 28-32) the major problems of the dataset have been dealt with and the regressions can be taken as shedding some light on the effect of R&D expenditure in industry on industry growth.

Having briefly summarized the results the next section (please see pages 43-44) will discuss these results thoroughly and relate them to the 'Swedish paradox' and situate them within the theoretical framework.

[37] Although not discussed in this dissertation, the sign of the co-efficient on labour is very interesting and could perhaps be a subject for further research. As this dissertation focuses on the interaction between R&D expenditure and economic growth it is not analyzed in this dissertation.

6.2 DISCUSSION

The results from the regressions above (please see pages 41-42) reveal that R&D expenditure in industry appears to have a substantial effect on industry growth (value added of industry). The effect of R&D expenditure appears to be the largest at time t. With time-lags the effect of R&D expenditure on industry growth decreases and is similar both for t-2 and t-4. However, the effect is still relatively large and is statistical significant. The conclusion that can be drawn from these regressions is that R&D expenditure in industry does appear to be a factor of industry growth in Sweden 1987 to 2007.

In addition to performing regression analysis it is important to situate the regression results in a theoretical context. In order to place the results in a theoretical context it is worth to reiterate the aim of this thesis. This thesis aims to disaggregate the 'Swedish paradox' with respect to the manufacturing industry. This dissertation also aims to shed some light on the impact of R&D expenditure in industry on industry growth as according to the 'Swedish paradox' the effect R&D expenditure is small. However, the results of these regressions reveals that on industry level there are no signs of a 'Swedish paradox' as the returns to R&D investments appear to be relatively high. It is true that a 1% increase in R&D expenditure does not yield a 1% increase in growth but the effect is still substantial. It therefore appears as if in industry R&D expenditure is an important factor of growth.

The substantial effect of R&D expenditure in industry on industry growth can be explained by examining how R&D funds are used. Going back to the data sources and the discussion of the statistics in *Section 5* (please see page 29-38) it can be noted that R&D expenditure compromises both funds given by the government and private funds. Investments made in R&D are used by firms to adjust their products to fit the market-place. It can therefore be argued that R&D is an ongoing and necessary process to keep up to date with a competitive market economy. In an ever-changing market-economy R&D activities are important to keep products up to date and attractive to consumers. As Sweden is a small, export orientated economy the products need to be attractive not only on the Swedish market but also in a competitive international market-place. It can therefore be argued that investing in R&D expenditure is of paramount importance in order for industries to remain competitive in a global political economy. It can therefore be argued that R&D expenditure is an important ingredient in achieving economic growth in an increasingly globalised world.

In addition to investing in R&D expenditure to keep products up to date with the marketplace, new products also need to emerge in order for industries to remain competitive. R&D expenditure is therefore used as a way to try to develop innovations, refine old ideas into new ones and perhaps create new ideas which provide impetus behind economic growth. The relatively large effect of R&D expenditure on industry growth may therefore also reflect the desire to create new innovations and attempt to generate new economic growth. It is true that it very hard to measure how many innovations arise from investments in R&D and it is difficult to say how important investments made in R&D are to new innovations. Nevertheless, the idea that R&D expenditure not only refines older products and older ideas to the current marketplace but also helps to build new engines from growth cannot be neglected.

Finally, the results of the regressions in this thesis contradict the idea of a 'Swedish paradox' at the industry level. The substantial effect of R&D expenditure in industry on industry growth in Sweden 1987 to 2007 may be a consequence of R&D expenditure in industry being more targeted than R&D expenditure at the aggregate level. It can be argued that industry spends on R&D in order to achieve economic growth. Perhaps it is even the case that R&D expenditure in industry is more carefully managed than R&D expenditure at the aggregate level. This idea of managing R&D is discussed a subject for further research and is developed in *Section 7.2* (see pages 49-54).

In conclusion therefore it is important to note that there are a variety of explanations as to why the effect of R&D expenditure in industry on industry growth is rather large. It has been noted that R&D can be seen as a process by which industry keeps up with the changing market-place and a way by which industry aims to provide impetus behind growth. It has been argued that perhaps R&D expenditure in industry is more targeted than R&D expenditure at the aggregate level. Whilst it is true that the results of these regressions cannot be considered as being definite but it is possible to draw some policy implications from these results. Some policy implications are therefore summarized in the section below (please see page 46-47)

6.3 POLICY IMPLICATIONS

The results of this study are believed to have some policy implications. The first and foremost conclusion of this dissertation is that the 'Swedish paradox' does not appear to exist at the intermediate level (micro-meso level). Although the results of this dissertation point to the importance of R&D expenditure in industry on industry growth some caution needs to be taken. The regressions presented in this dissertation are for the time period 1987 to 2007 and as the past can only give us an indication of the future the policy implications cannot be believed to be definitive. However, as R&D expenditure does appear to have an effect on industry growth it can be argued that investing further in R&D expenditure appears to be a good idea.

The results of the regressions reveal that in the Swedish manufacturing industry from 1987 to 2007 the returns to investments in R&D are relatively high. In fact R&D expenditure has an effect on industry growth both at the current year and also has a lagged effect of several years (2 years and 4 years). From this large effect of R&D expenditure on industry growth it can be argued that spending more funds on R&D in industry is a good idea. Therefore perhaps spending on R&D has the potential to become an engine of growth of Swedish manufacturing industry. From the empirical results of this study R&D expenditure has such a large effect that more funds and knowledge should be placed in furthering R&D activities.

As discussed in *Section 2.1* (please see page 7-12) Sweden is a small, export oriented economy dependent on the success of the manufacturing industry. It could even be argued that in an increasingly globalized world Swedish manufacturing needs to find a competitive edge. Sweden is unlike countries with low labour costs as the unions are powerful and closely intertwined with the state. Sweden is therefore unable to devalue wages in order to keep Swedish manufacturing growing. In addition to this Sweden is not a member of any monetary unions such as the EMU and Swedish manufacturing is therefore very sensitive to swings in the currency. It could be argued that as borders blur and Sweden integrates further into the global political economy Sweden needs to work on improving its manufacturing sector. In an increasingly global market-economy where only the fittest survive Sweden perhaps needs to invest further in keeping the manufacturing industry up to date.

Therefore investing further in R&D may serve the Swedish manufacturing industry and help Sweden to remain competitive in an international market-economy.

7. CONCLUSION

7.1 CONCLUSION

The aim of this dissertation was to provide insight on the impact of R&D expenditure in industry on industry growth (value added in industry) in Sweden 1987 to 2007. The interaction of R&D expenditure and industry growth was believed to be of interest as endogenous growth theories point to R&D expenditure as a factor of growth. In addition to this R&D expenditure is prioritized in public policy as both political blocks in Sweden vows to increase investments in R&D. Empirical evidence on the other hand tells a different story. Scholars have formulated the 'Swedish paradox' implying that the high level of public R&D expenditure in Sweden does not yield substantial economic growth. This dissertation has aimed to partly disaggregate the 'Swedish paradox' by shedding some light on the influence of R&D expenditure on industry growth of the manufacturing industry. To date research has focused largely on the aggregate level and little effort has been placed on analyzing the effect of R&D expenditure on economic growth at the micro and meso-level. Therefore this thesis has aimed to provide analysis of the effect of R&D expenditure on growth at industry level in Sweden.

By focusing on the manufacturing industry it was found that R&D expenditure does appear to have a substantial effect on industry level. To quantify the effect of R&D expenditure on industry growth a panel-data analysis was performed by running a 'fixed-effect' model specification. The regressions were run using R&D expenditure in industry as the explanatory variable, value added of industry as the variable of interest and labour and investments as controlled variables. Five industries provided a balanced panel and enabled different parts of the manufacturing industry to be represented.

The results of the regressions point to the importance of R&D expenditure for industry growth. Therefore on industry level there is not much evidence of a 'Swedish paradox'. Whilst it is true that a 1% increase in R&D expenditure does not yield a 1% increase in value added of industry the effect is still substantial as a 1% in R&D expenditure at time t does yield a 0.25% increase in value added of industry. . The results of this thesis therefore emphasize the importance of R&D expenditure in industry as a factor of industry growth. It is true that some caution needs to be taken when interpreting the results but it is still possible to draw some policy implications from this dissertation. Firstly, it can be argued that as investing in R&D in industry yields economic growth more funds should be targeted at the manufacturing industry. Secondly, the idea that R&D expenditure enables economic growth in the manufacturing industry in Sweden might provide a tool for Swedish manufacturing to remain competitive in an increasingly global market-economy. It can be argued that in a world with borders blurring and an increasingly international market-economy emerging strengthening Swedish manufacturing industry is important. This thesis suggests that R&D expenditure is an important ingredient in achieving economic growth. As Swedish manufacturing is becoming increasingly internationalized, investing in R&D in industry might prove to be an engine of economic growth in the global political economy of the 21st century.

Nevertheless, the policy implications summarized above are uncertain. If the anatomy of the effect of R&D expenditure on economic growth is to be more certain, more research needs to be done. By performing more research new dimensions of the 'Swedish paradox' can be uncovered and the interaction between R&D expenditure and economic growth better understood. Further research enables more concise R&D strategies to be developed and may even help Sweden in developing a future competitive advantage in a global market-economy. In the section below some further ideas for research are summarized.

7.2 SUGGESTIONS FOR FURTHER RESEARCH

This thesis has examined one dimension of the impact of R&D expenditure on economic growth by shedding some light on the influence of R&D expenditure in industry on industry growth in Sweden 1987 to 2007. Focus was placed on the industry level as this thesis aimed to partly disaggregate the 'Swedish Paradox' by moving away from the aggregate level to using industry as the unit of analysis. If the mechanics of R&D expenditure on economic growth are to be better understood more research needs to be done and more effort needs to be put on disaggregating the 'Swedish Paradox'. Some suggestions for further research are therefore briefly summarized in this section.

ZOOMING IN ON THE MICRO-LEVEL (FIRM-LEVEL)

This thesis focused on the industry-level. However, it would be interesting to zoom in on the micro-level by looking at the effect of R&D expenditure on the growth of firms. This would be interesting as the firms can be thought as being 'profit-maximizing'. It can be argued that firms face a trade-off between investing in R&D and making a larger profit or spending on some other necessity. At the same time firms have to invest in R&D to keep up with the global market and stay profitable in an increasingly competitive market-place. Therefore closely examining the link between R&D expenditure and economic growth in firms enables the interaction between R&D expenditure and economic growth to be analyzed.

Analyzing the effect of R&D expenditure at the firm-level enables another dimension of endogenous growth to be uncovered and allows for further disaggregation of the 'Swedish paradox'. As a student it is difficult to conduct a study at the firm-level due to data availability. However, for an academic (or PhD student employed at a university) the relationship between R&D expenditure at the firm-level and growth of firms can be thoroughly investigated using micro-data provided by SCB (in the form of the MONA database) or by using databases such as CIDER at the university of Lund.

EXAMINING THE LINKS BETWEEN ACADEMIA AND INDUSTRY

It would also be interesting to look at other dimensions of the 'Swedish paradox'. For example it would be interesting to disaggregate the 'Swedish paradox' furthur and analyze the economic growth resulting from the funding given to Swedish universities. It would be interesting to examine the links between academia and industry and how the funding supplied to universities enable spill-over effects on industries. The interactions between academia and industry are important as they enable knowledge developed at universities to be transferred into 'useful knowledge' for the overall economy.

In addition to examining the links between academia and industry it would be interesting look at how the funds given to research at universities are distributed. By analyzing how much of the funds get stuck in administration and how the funds are divided between different researchers a clearer picture of the distribution of R&D expenditure in academia would emerge. Performing a study like this would have policy implications as it would be possible to see how funds are best distributed to yield the most economic growth. Examining the effect of R&D expenditure at universities would also help to analyze how funds are best distributed to pave the way for successful universities in an increasingly globalized market for education.

The links between academia and industry could be examined by using case studies. It would also be possible to examine how many research projects are linked to industry and closely examining the distribution of funds at Swedish universities.

LOOKING AT THE DIVISION OF FUNDING BETWEEN SUBJECTS

In addition to examining the links between academia and industry it would be interesting to examine how funds invested in R&D have been distributed in academia for the past 20-30 years. In proposals such as the one put forward by the current Swedish government all academic subjects are given funding. However, the actual sums are not specified in the current proposal and it would be interesting to go back in time and see how the funds have been spent historically. Looking at the distribution of funds historically is interesting as it is possible to learn lessons from the past by examining which investments have yielded a high economic return. Performing a study like this is very interesting but it is important to note that even though a subject does not yield any economic growth does not diminish its importance.

A study like this could be done by looking at databases from SCB and perhaps going into the archives of universities. In addition to this case studies could be used.

HIGH-TECH/ LOW-TECH DIVISION

The aim of this thesis was to disaggregate the 'Swedish paradox' with respect of the Swedish manufacturing industry. It would be interesting to disaggregate the 'Swedish paradox' further into high-tech and low-tech sectors. Kander and Ejermo (2006) have compared Sweden to other countries by analyzing high-tech and low-tech sectors. It would be interesting to add to their research by conducting an econometric analysis to see if the returns to R&D investments in high-tech sectors are larger than the returns to R&D in low-tech sectors. As the manufacturing industry is a diverse industry researching the high-tech/ low-tech returns on funding would give a clearer picture of returns to R&D in different sectors in the manufacturing industry.

However, researching this question is difficult due to data availability. The data sources used for this thesis do not include enough material to conduct a study of this kind. It would therefore be necessary to turn to the data held in databases such as CIDER which is not readily available to students.

LOOKING BEYOND NATIONS (USING A LARGER UNIT OF ANALYSIS)

In a paper in *Ekonomisk Debatt* from 2007 by Ejermo, Kander and Schön (as mentioned in *Section 2.3* please see pages 16-18) it is claimed that the 'Swedish paradox' is best solved by lowering the expectations created by the endogenous growth modelers. In the same paper the authors argue that the politics of innovation should focus on a larger geographical basis. The authors of the article write that the politics of innovation should move away from the nation and focus on a supranational level (such as the EU) or on the global level. The authors argue that R&D expenditure should be increased on the global level in order to increase overall economic growth.

The claim made by Ejermo et al. (2007) is interesting and deserves to be empirically investigated. In the article by Ejermo et al. (2007) this claim is not backed empirically. The authors do point to there not only being a Swedish paradox but also a European paradox and an American paradox. It would therefore be interesting to analyze how R&D activities could focus on the global level and how such activities can yield growth on a global level.

Examining how R&D activities could influence growth on a supranational or global level is difficult. It can even be argued that the innovative policies of the EU are loosely defined as the nation-state maintains a lot of room to maneuver in economic policies. Looking on a larger geographical unit is therefore difficult. To get an idea how R&D expenditure affects growth in the EU or on a global level it would however be possible to run a panel-data regression of some countries. For OECD countries this data can be accessed from OECD publications.

EXAMINING THE INTERACTION BETWEEN R&D EXPENDITURE AND ECONOMIC GROWTH IN OTHER OECD COUNTRIES

Another suggestion related to the suggestion above would be to examine the link between R&D expenditure and economic growth in other developed countries. It would be interesting to expand the scope and examine relationship between R&D expenditure and economic growth in other OECD countries.

Conducting a study of this kind would enable a comparison between countries and a discussion of the differences and similarities. Since there is a relatively large body of literature on the ’Swedish paradox’ it would be interesting to see if there is a similar relationship in other developed countries.

Analysing the relationship between R&D expenditure in industry and industry growth in various countries can be done using a similar method to the methodology used in this thesis. Data can be collected from OECD and the national bureaus of statistics and regressions could be run using panel-data. At the aggregate level it would be possible to collect figures for aggregate R&D expenditure from the OECD (under the classification GERD). It would be possible to use GDP as a measure of economic growth and then run panel-data regressions and see if they yield any statistical significant results.

A study at industry level could be done by using a similar method to this thesis. The statistics for R&D expenditure could again be supplied by OECD (under the classification BERD) and value added could be collected from national bureaus of statistics. The results from the industry level would enable a comparison between countries. It would be possible to see in which countries investments made in R&D yields the most economic growth. A study of this kind could therefore provide fertile ground for a discussion on which country has the good infrastructure for transforming R&D investments into economic growth.

The result from the aggregate level would enable some more light to be shed on relationship between R&D expenditure and GDP growth. Statistically significant results would enable an answer to the question whether there is an ’empirical paradox’. If the regressions would yield non-statistical significant results the ’empirical paradox’ would be supported. If the ’empirical paradox’ was supported it would be possible to have a general discussion about the dynamics by which R&D expenditure is transformed into economic growth.

<u>ANALYZING R&D STRATEGY BOTH AT THE AGGREGATE AND MICRO-LEVEL</u>

The final proposal for future research I’m going to put forward in this dissertation is to analyze R&D strategy at both the aggregate and micro-level. In the economic sciences decisions are usually taken by ‘profit-maximizing agents’ attempting to make as much economic gain as possible. It could be argued that investing in R&D is a way to keep up with an international market-place and remaining competitive in a globalised world. As a lot of funds are spent on R&D both at the aggregate level and the micro-level it would be very interesting to analyze how the decisions to invest in R&D are taken.

Analyzing R&D strategy therefore enables another dimension of the interaction between R&D expenditure and economic growth to be uncovered. By looking at the intentions behind investing in R&D a psychological dimension of endogenous growth could be uncovered. It would be interesting to interview both policy-makers and managers at firms to uncover how R&D is thought to stimulate growth and how decisions to invest in R&D are taken.

A study of this kind could be done by using both structured and semi-structured interviews of a large sample of managers and policy-makers and so try to draw a conclusion as to what decisions are behind investments made in R&D.

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APPENDIX

RESULTS OF DIAGNOSTIC TESTS

TEST 1: UNIT ROOT TEST

Pool unit root test: Summary

Date: 04/24/10 Time: 16:58

Sample: 1 11

Exogenous variables: Individual effects

Automatic selection of maximum lags

Automatic selection of lags based on SIC: 0 to 1

Newey-West bandwidth selection using Bartlett kernel

Method	Statistic	Prob.**	Cross-sections
Null: Unit root (assumes common unit root process)			
Levin, Lin & Chu t*	-6.55952	0.0000	20
Null: Unit root (assumes individual unit root process)			
Im, Pesaran and Shin W-stat	-3.30155	0.0005	20
ADF - Fisher Chi-square	74.5632	0.0007	20
PP - Fisher Chi-square	82.0494	0.0001	20

TEST 2: CORRELOGRAMS BETWEEN LAGGED VARIABLES OF R&D EXPENDITURE

Chemicals and Chemical Products

	LNRD	LNRD(-2)	LNRD(-4)
LNRD	1	0.86	0.72
LNRD(-2)	0.86	1	0.91
LNRD(-4)	0.72	0.91	1

Furniture and Other

	LNRD	LNRD(-2)	LNRD(-4)
LNRD	1	0.59	0.34
LNRD(-2)	0.59	1	0.41
LNRD(-4)	0.34	0.41	1

Textiles, textile products, leather and footwear

	LNRD	LNRD(-2)	LNRD(-4)
LNRD	1	0.29	0.18
LNRD(-2)	0.29	1	0.72
LNRD(-4)	0.18	0.72	1

Paper, paper, paper products, printing and publishing

	LNRD	LNRD(-2)	LNRD(-4)
LNRD	1	0.16	0.12
LNRD(-2)	0.16	1	0.10
LNRD(-4)	0.12	0.10	1

Food, beverages and tobacco

	LNRD	LNRD(-2)	LNRD(-4)
LNRD	1	0.37	0.055
LNRD(-2)	0.37	1	0.39
LNRD(-4)	0.055	0.39	1