LUND UNIVERSITY
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The Swedish R&D Paradox – The Basis for its Existence and its Policy Implications

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Abstract: This paper explores the validity of assuming the existence of a Swedish R&D paradox based on the relationship between R&D expenditures and economic growth, and what implications the existence of such a paradox ought to have on policies that concern R&D expenditure. Consequently, in the first instance, the relationship between Gross Expenditure on Research & Development (GERD) and Gross Domestic Product (GDP) is de-obfuscated and empirically explored based on actual data from 2000 to 2008 for all EU countries as well as some other European and world leading economies. In the second instance there is a discussion of the 3% R&D intensity aim set up by the Lisbon agenda and of increasing R&D investment incentives through tax reductions in Sweden as recently has been proposed by VINNOVA.

Key words: Economic growth, GDP, GERD, Innovation, R&D, R&D Intensity, Swedish R&D Paradox

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1 Introduction

The so called Swedish R&D Paradox stems from an assumed relationship between Research and Development (R&D) expenditures and economic growth, and the belief that high levels or high growth of the former should result in high levels or high growth of the latter. It is however argued that Sweden does not follow this pattern, but that it only experiences mediocre growth in spite of having one of the highest, if not the highest, R&D intensities in the world. Consequently this paper will look at the actual levels of R&D expenditure and GDP growth across countries to see if such causality indeed exists, and if so how strong it is. This approach has been chosen as I believe that one could only talk about a Swedish paradox *if, and only if*, there is a clear causal relationship for other countries and that Sweden deviates from this trend. Consequently, if no such relationship exists, or if it is very weak, then the basis of the Swedish R&D Paradox is undermined as by definition then the others would also have to be deemed to be “paradoxes”. Moreover, if the causality is negligible then we perhaps ought to stop trying to attribute such a great deal of economic growth to R&D expenditures. The bottom line then becomes: how big of an effect can we expect Gross Expenditure on Research and Development (GERD) to have upon Gross Domestic Product (GDP)? If the answer is that the causality is low then the Swedish R&D Paradox is neither planted in firm ground, nor is it even treading water, it would indeed be no more than an air castle built upon loose speculations and normative ideas that *assume* that increased R&D spending *ought to* increase GDP growth.

1.1 Structure and Research Questions

Since the paradox is built on the relationship between GERD and GDP – and its ratio – more commonly known as the R&D intensity, I will attempt to evaluate this relationship and whether or not such a connection in and out of itself can actually explain patterns of growth. The results from this exploration will subsequently form the basis for the discussion of the existence of a Swedish R&D Paradox through the use of an underlying assumption that its existence hinges upon the existence of a causal relationship between the two variables in general, and that Sweden would have to deviate from this trend in order to be seen as a paradox. Once the relationship between the two variables has been explained, qualified and quantified there will be a discussion of the proposed Swedish paradox, and what Policy implications the existence of such a Paradox ought to have. Consequently this paper will have three aims:

- Try to estimate the validity of the argument that there is a strong causal link between R&D expenditure and GDP growth.
- Apply the findings of the above analysis to the debate on the Swedish Paradox.
- Assess what policy implications the existence of such a paradox ought to have.

Furthermore, the thesis has been divided into six distinct chapters as follows:

(Conceptual framework within brackets)

1. Introduction
2. Methodology
3. Background
4. Empirical Investigation, which is divided into two sections:
    - Descriptive Statistics (descriptive, positivism)
    - Explorative Statistics (exploratory, positivism/realism)
5. Policy Implications (prescriptive, normativism)
6. Conclusion

The three main issues that this paper concerns are tackled with the use of different techniques. Whilst the discussion of the Swedish R&D Paradox will run throughout the entire paper, as its presence lies at the heart of each topic, the other two issues will be dealt with within more confined settings. The exploration of the GERD / GDP relationship will be dealt with in chapter 4, which will use descriptive and explorative statistics to facilitate a close examination of the validity of expecting a strong causality between GERD and GDP growth. While the last issue at hand will be treated in chapter 5, which will turn to what policy implications the existence of a Swedish Paradox *ought* to have on two different policies, one existing and one proposed. Namely, the 3% R&D intensity aim set up by the Lisbon Agenda; and increasing the incentives for undertaking R&D in Sweden via tax reductions, respectively.

2 Methodology[1]

In accordance with Saunders, Lewis and Thornhill (2007, p. 40) this chapter will outline "how [I] intend to go about achieving [my] research objectives." It will, as thoroughly as needed explain the methods that will be employed as well as the reasoning for choosing these methods. Consequently this section will deal with chapters 3 through 5. However, it will also describe the reasoning behind the structure of concluding chapter, i.e. the methods that will be employed in the synthesis and evaluation of the results of the entire paper.

[1] This chapter has largely been adapted from "The Swedish Paradox – A survey of the literature and empirical investigation into its roots based on an assumed GERD/GDP relationship" (2010) written for *EKHM04 Research Design*.

2.1 Defining the Approach

This paper could be deemed inductive or deductive depending on from which point of view one would like to depart. On the one hand the discussion goes from the general, in the form of the framework of the definition of R&D intensity, and then takes it to the discussion of one specific regional case, namely, the Swedish Paradox. Viewed in this light it would have to be deemed deductive as it follows a progression from the general to the specific. However, the reasoning could also be turned upside down and it could be argued, using the definition provided by Saunders et al. (2007, p. 57), that it more so makes use of an inductive rather than deductive approach as it tries to find a pattern in the data which is then related to the existing literature, not vice versa. Support for it being more of an inductive approach can also be found in the words of Dew (2007, p. 435) from which it can be seen as using an inductive approach as it tries to “[set] aside prior theories and attempts to build up an understanding of the world from the data[,]” the latter statement would however only fit if the framework is deemed to be the specifics of the Swedish paradox as opposed to the specifics of the GERD / GDP framework. That said, irrespective of how the approach of the paper is formally classified there is a need for an explanation of the assumed relationship between R&D and growth as well as recapitulation of the debate on the Swedish R&D Paradox before diving into the empirical analysis. Consequently chapter 3 is in place as to present the leading views on these subject; however, this chapter is not necessarily in place to create a basis for fully explaining the GERD / GDP relationship nor explaining the potential existence of the Swedish R&D Paradox, but is more so in place as to help guide the reader as to why I am exploring the chosen field and what potential problems there may be with the underlying assumptions that the paradox is built upon.

As pointed out in the previous paragraph, this paper might be deemed as using an inductive approach; however, I believe it to be rather firmly grounded in positivism, or at least realism. It might then seem odd, if not outright contradictory if following the schema presented by Saunders et al. (please see Saunders et al. 2007, p. 102), to use an inductive approach while yet calling it largely grounded in positivism and realism; however, I would argue that these concepts and approaches are not necessarily quite as much of polar opposites as they are painted out to be. Furthermore it should perhaps be added that it is my belief that there is a natural progression in the paper from descriptive to prescriptive and from positive to normative, lending support to the notion that the use of one conceptual framework does not preclude the use of another.

2.2 An overview of the approaches and methods used in chapters 3 – 6

This section will present a short outline of the approaches and methods used in the empirical and analytical chapters of this paper.

2.2.1 Background

This chapter is largely in place as to sort out the leading ideas on the subject of R&D expenditure and its assumed effect on growth, along with the basis for the discussion of the Swedish R&D Paradox. It will nonetheless, in accordance with Saunder et al. (2007, p. 57) "not [...] provide a summary of everything that has been written [... but will ...] review the most relevant and significant research on [my] topic."

2.2.2 Descriptive and Explorative Statistics

The descriptive statistics section will present past and present (2008) levels of real GERD and real GDP as well as the R&D intensities for all European countries as well as some other leading economies, namely Japan and the United States. The main unit of analysis is the 21st century, as to see if one can on a strictly descriptive level detect a Swedish R&D Paradox during this period, irrespective of whether it may or may not have existed in previous periods. The explorative statistics section aims to evaluate the relationships between the above mentioned variables; however, this section limits itself to investigating these relationships within the European Union. Furthermore this exploration will involve three separate analyses that aim to test whether high growth countries indeed have higher R&D intensities than low growth countries, as well test for correlation and potential causality between real GERD and real GDP.

2.2.3 Policy implications

Based on the findings from the previous analyses this chapter will discuss the appropriateness of the Lisbon Strategy's 3% R&D intensity goal for all member states, and for increasing the incentives for performing more R&D in Sweden. This chapter is, as previously mentioned, of a normative nature and reflects *my views* of what the correct policy measures ought to be and is based upon the results of *my empirical investigation* along with the adjacent literature on the topic.

2.2.4 Conclusion

In accordance with Rowntree's (1987) definition of synthesis as "the ability to arrange and assemble various elements so as to make a new statement or plan or conclusion – a unique communication [,]"[2] I will attempt to summarize, synthesize and if possible harmonize the findings from the preceding sections in an effort to make the paper feel as one coherent unit of analysis even though it has spanned more than one dimension of the main issue at hand, namely the Swedish R&D paradox.

3 Background

God cannot alter the past, but historians can. – Samuel Butler

There seems to exist a common belief among researchers that R&D increases economic growth through an expansion of the resource and knowledge base, which then results in the existing resources being used more efficiently (Fagerberg, 1994; Grossman and Helpman, 1991; Jones, 1995). Contingent upon R&D leading to innovations[3] and technological change I cannot argue that this would be sound reasoning. Nonetheless, it is rather likely that far from all R&D endeavours will lead either to a deepening of the knowledge base or to commercialized products for that matter. Consequently there is a need to look a bit closer at some of the underlying assumptions of the effect that R&D expenditure is thought to have upon economic growth, as well as the validity of these arguments.

3.1 Endogenous vs. exogenous growth

The models that attempt to explain economic growth have evolved over time. With a broad brush one may say that there have been three generations of growth models, those who attribute growth to savings and investments, i.e. Harrod-Domar type models; those who believe that growth is due to capital and labour inputs along with technological change where the latter is deemed exogenous, namely Solow type models; and lastly those who have their underpinnings in the Solow model but who assume that technological change is endogenously determined. Traditional neoclassical growth models, such as the Solow model[4] – which uses a simple Cobb-Douglas production function ($Y = AK^{\alpha}L^{\beta}$) where growth is contingent upon two traditional factors of production, capital and labour (K and L) and a residual (A) – presume that growth is exogenously determined. Moreover, these types of models assume that there are diminishing returns to both of the traditional factors of production but constant returns to scale i.e. [α and β <1], but [$\alpha + \beta = 1$]. Additionally, they tend to assume perfect competition and consequently α and β can be taken as representing the

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[2] Rowntree 1987, p. 103; quoted in Saunders et al. 2007, p. 541.
[3] Innovation should not be equated with invention as the former represents the commercialised form of the latter. Consequently innovation *may* lead to growth, but invention need not lead to growth.
[4] First introduced by Robert Solow in 1956.

share of the output that can be contributed to labour and capital. The residual (*A*), also known as the Solow residual, represents the Total Factor Productivity (TFP) which – as once put by Domar (1961. P.712) – accounts for all “increases in output not accounted for by explicitly recognized inputs.” In essence then, growth in the Solow type models hinges upon the residual, yet the residual is exogenously determined and is thus not assumed to be contingent upon the growth or the other factors in the model. As such the residual, which often is taken as representing the technological change is, as asserted by Abramovitz (1956, p. 8), indeed to a certain extent “a measure of our ignorance.” Moreover the way to go about measuring the effect of R&D upon growth through the use of this model then often results from estimations of the relationship between the residual and GERD – typically tested using Denison’s growth accounting approach.[5]

Over the past few decades it has however become more common to view the residual as endogenous, i.e. as stemming from something else within the function as opposed to being determined *ex gratia* by some other undefined factor. Scholars such as Romer (1990); Grossman & Helpman (1991); and Aghion & Howitt (1992) are among some who have moved away from the traditional Solow type models with exogenous growth and started to treat the productivity growth (TFP) as stemming from intentional innovation that in turn hinges upon the inputs into the innovation process. Consequently, in latter decades much emphasis has been placed on this form of endogenous growth with rational profit maximisers who invest in R&D in order to reap higher profits, rather than assuming that productivity growth stems from the rate if innovation which is exogenously determined. Moreover, as R&D capital is largely nonexclusive and often leads to spillovers[6] the inclusion of R&D in the production function may thus lead to the possibility of increasing returns to scale. This of course is not to say that growth in the Solow model with exogenous growth is not contingent upon technological change, as Solow indeed contributes much of the growth to the residual,

[5] A summary Denison’s approach can be found in Kendrick and Grossman (1980).

[6] Griliches (1995, pp. 65-66) distinguishes between two types of spillovers, the first, which could be deemed a positive spillover, comes through an enlargement of the knowledge base which is spilled-over from one industry to another. The other can be seen as a negative spillover, where actors can acquire the output of the R&D undertaken for a price that is below that of the inputs. This latter type of spillover tends to lower the incentives to invest in R&D, but it can furthermore create accounting problems as the industry/ firm that paid for the inputs need not receive the appropriate outputs. Moreover, the social and private returns to spillovers may be assumed to vary greatly with different types of innovations; however, on average the social return tends to be higher than the private return. For instance Mansfield et al (1977) show, through various case studies of agricultural and industrial innovations, that the social return is far higher than the return to the innovator, i.e. the private return. That said, these type of studies could be argued to not reflect the overall returns to spillovers; however, it should perhaps be rather clear that spillolvers do indeed exist, as one can see casual evidence of them on an everyday basis. It is for instance easily observable how one company comes up with a new technology and how others follow suit almost immediately, or at least too quickly to assume that such an effect does not exist.

but rather, that just as the growth hinges upon the residual so does the residual hinge upon something else. Furthermore, is it also quite likely that even the traditional factors of production are affected by the level of R&D, a point driven home by for instance Bernstein and Nadiri (1989) who claim that changes in R&D expenditure affect the demand for labour, energy and physical capital as R&D expenditures tend to decrease the demand for labour and increase the demand for capital.

3.2 What is R&D?

R&D, according to the Frascati Manual,[7] constitutes "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." Moreover, R&D can be broadly categorised into three categories as follows:[8]

- Basic research – which can in itself be divided into two categories:
  - Broad range, or *pure*, basic research – a type of research that is seldom sold i.e. it typically has little effect on economic growth, at least in the short run. That said the goal of this research is not necessarily to increase growth directly but can more so be seen as being a form of *advancement of knowledge for the sake of advancing the knowledge*. Nonetheless, as the knowledge builds up in the longer run there is of course a distinct possibility that it would indeed have an effect on economic growth.
  - Oriented basic research – is much the same as the previous category, however one key difference is that it serves to increase the knowledge base within a certain field; a knowledge base which is meant to help solve present and future issues or problems pertaining to this *particular field*.

- Applied research – is the second category of research whose aim is to develop new knowledge, however it is typically geared toward finding new solutions to a *specific problem*. As such it is less broadly applicable, but the results may well be patented thus limiting their use of others. Consequently for firms – who we can deemed to be profit maximizers – tend to be more willing to undertake this form of research as opposed to basic research as it can, at least in the short run (until the patent runs out), grant them an advantage over other firms.

- Experimental development – which is the *development* of new products or materials.

As such it may not be hard to imagine that R&D ought to lead to economic growth, however in order for R&D to have an effect on growth directly it needs to lead to innovations i.e. commercially viable products or services. However, as previously pointed out one may perhaps also assume that basic research may not have an effect on growth in the short run; it

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[7] The international handbook for how to collect R&D statistics. The quote has been taken from the *OECD Factbook 2007*, p. 46.
[8] R&D classifications are based on the definitions given in the Frascati Manual (2002) section 4.2.2, pp. 77-9.

may nonetheless very well lead to positive effects on growth in the longer run. The main argument for claiming that R&D has an effect upon growth is nevertheless via innovations, yet how strong is the argument that R&D in all actuality leads to innovation?

3.3 R&D as a measurement of innovation

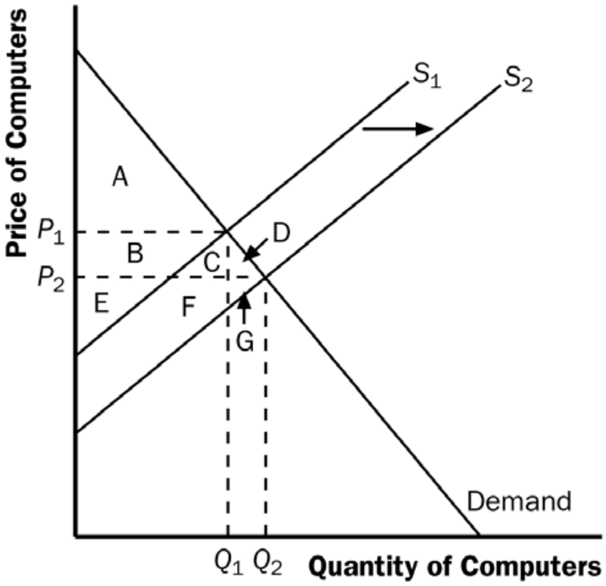
It is not only hard to measure the impact of innovations upon economic growth due to GDP encompassing so many other variables, many of which may also be influenced by each other. The relationship is further complicated by the fact that the measurements used to measure innovations themselves are far from perfect. Methods such as the Community Innovation Survey (CIS) approach and the Literature-Based Innovation Output (LBIO) method have been developed to measure innovations; however, even though these measurements may reflect the innovation process better than other measures have been able to do in the past they can nonetheless be heavily influenced by the respondents in the case of surveys, editorial biases in the case of the use of magazines and journals, as well as researchers' biases during the data collection processes, which consequently applies to both methods. These approaches are – irrespective of their respective flaws – nonetheless perhaps preferable as compared to for instance R&D and patents in gauging the level and effect of innovations. However, due to the difficulties of quantifying innovations the R&D expenditure is often used as a proxy for innovations, yet the use of this proxy indeed has a major drawback – it only measures the inputs of the innovation process. To counter this flaw patents and publications are often used as proxies for the output of R&D; however, how well do these measures in fact reflect innovations? The bottom line is this: there is no guarantee that R&D activity will lead to inventions. Moreover, there is no guarantee that even if it does lead to inventions that these in turn will lead to patents – even if commercialized – as some innovations simply cannot be patented due to their intrinsic nature or because the patenting process might be considered too costly compared to the potential profit that could be reaped. It may be safer to assume that R&D that is geared towards increasing the general knowledge will be better reflected in the number of publications than products will be by patents, but this then raises the question of how much of an the effect of this type of output would indeed have on economic growth; at least in the short run the answer would have to be very little. With this in mind assuming a strong causality between R&D and growth is arguably already on rocky grounds. In addition, as already mentioned, R&D only reflects the inputs into the innovation process; however, it may not even do this remarkably well. According to the Frascati Manual the R&D measurement, which should reflect the level of "research comprising activities" for instance excludes education and training as well as equipment and machinery, factors that in my opinion ought to have an impact on innovations – or the rate at which inventions are generated and goods produced.[9] Consequently one could perhaps question even the categorisation of the inputs of the innovation inputs themselves. After all, if these inputs do not reflect the output, i.e. the innovations, all that well, and it is this output that in fact has an impact on economic growth, then we ought to perhaps ask ourselves how strong the argument that R&D ought to lead to economic growth in all actuality is? It should additionally of course also be mentioned that just as R&D need not translate into innovations, innovations need not stem from any considerable amount of R&D, which in my opinion further deteriorates the assumed strong causality between the R&D expenditure and economic growth.

3.4 The assumed relationship between economic growth and R&D investments

The presupposed effect of R&D expenditure upon growth largely stems from the assumption that R&D expenditure ought to lead to innovations; a relationship that was explored in the previous section. Based on the preceding discussions it may then be more appropriate to rephrase the relationship to *innovation leading to growth* as opposed to *R&D leading to growth* as R&D need not translate into innovation and consequently these activities need not have a direct effect upon economic growth. However, under the assumption that R&D indeed leads to innovations and technological change, the benefits from R&D can at the firm level be captured in a simple supply and demand diagram as reflected by figure 1 below.

[9] For further details on the Frascati Manual's R&D exclusions, as well as the exceptions to these exclusions, please see the Appendix.

Figure 1 – Economic gains from an innovation



The figure has been replicated Mankiw, N. G., R. D. Kneeborn, J. McKenzie and N. Rowe's *Principles of Macroeconomics*, 3rd Canadian edition, p. 140.

Through this graphical depiction it is relatively easy to understand what impact innovations, at the firm level, *can have* on growth and consequently what impact R&D investments *could have* on growth. In short the economic gains can be summed up as follows: initially the surplus gained by the firm, i.e. the producer surplus, amounts to areas B and E, and the consumer surplus to area A. The cost saving innovation shifts the supply curve rightward and reduces the price from P_1 to P_2 whilst increasing the output from Q_1 to Q_2. In effect the consumer surplus after the shift amounts to areas A, B, C and D, whilst the producer surplus becomes the sum of the areas E, F and G. Consequently, holding everything else constant the consumers unambiguously gain from the innovation while producers only gain as long as the sum of areas F and G is larger than area B. As such, if the supply shift would not be coupled by for instance a decrease in the production cost per unit or a shift in demand it is not a clear-cut case that firms would indeed invest in such an innovation. If the firm does not invest, this would however in terms of the social benefit perhaps be seen as being less than optimal as the total surplus of C, D, F and G would be foregone. However it should be further noted that the innovator is assumed to be the firm itself in this case and that perfect competition prevails.

R&D can also be seen as a tool for the technological leaders to push out the production possibility frontier (PPF) when the existing resources have already been utilized to the maximum. Therefore it is thought that R&D can help shift the frontier outwards and consequently enable further growth where there before was no more room for such an expansion. Subsequently, it could be the case that R&D investments need not have as much of an effect on growth for a less developed economy, as they would for a developed economy as the lesser developed economy could be argued to not yet have reached the PPF. Moreover R&D investments may be yet more vital to the technological lead countries, i.e. those countries that are at the technological frontier as they may benefit relatively less from international spillovers as well as being heavily dependent on the export of R&D intensive products. In light of this it could thus be argued that it would be cheaper and perhaps even more effective for a developing economy to grow solely through adopting already existing technologies rather than trying to develop new ones. Björn Asheim (2000, p. 427) for instance stresses that developing regions are indeed often led onto this path of adoption and adaption. However, true as this may be, I believe that the question is not whether or not they follow such a path, but more so if they ought to. If it is indeed the case that it is more efficient for lesser developed countries to adopt already existing technologies could it not then for instance in the EU case be argued that the cohesion of the union indeed hinges upon the lesser developed countries "freeriding" on the more developed countries' R&D expenditures rather than increasing their own R&D expenditures? I would argue that this may very well be the case and that " '[b]orrowing' and adapting technologies that the technological lead countries control today is [indeed] an important key to development" as Lundvall (2008, p. 112) points out. This of course means that in the short run these economies would have to be deemed as followers, yet I would argue that they are not locked in as followers, but that once the lesser developed economies have reached a certain level of development they too perhaps ought to put more efforts into R&D. As such it may be more beneficial for the EU as a whole if the lesser developed economies first "freeride" to then pull their own weight, instead of pushing these economies to increase their R&D expenditures while still standing on a pair of legs that can barely hold their own weight. In effect, the 3% R&D intensity aim set up by the Lisbon Agenda may be better suited as a goal for the developed member states and not the lesser developed ones, a point that will be returned to in chapter 5.

Furthermore it may be argued that the size of the economy, i.e. the size of the population, may matter as it in the first instance allows for a deepened specialisation – a notion that in fact traces all the way back to the classical canon and Adam Smith. Moreover size may matter as it is indeed the factor of the production function that carries the most amount of weight on its shoulders (its elasticity is typically assumed to hover around .7); however, it could also play a role in the relationship with R&D more explicitly as it may be seen as increasing the absorptive capacity of a country under the premise that spillovers are somehow constrained by the national borders. On the other hand the spillovers themselves may for instance be argued to increase with the level of trade, as explored by Coe and Helpman (1995, p. 875) who conclude that "R&D may have a stronger effect on domestic productivity the more open an economy is to international trade." That said, the effect of spillovers may also, as argued by Verspagen (1995), depend on the already existing knowledge that the economy possesses, as a certain level of knowledge is needed to able to absorb such spillovers.

Even if increasing the R&D expenditure may lead to more innovations it is likely that their effect on the economy will show up with a certain time lag. Firstly, in some cases, take pharmaceuticals for instance where there may be a considerable lag between the initial research and the release of the product as the drug needs to be developed, tested and then pass various health inspections before it can reach the store shelves. Secondly, there can also be an implementation lag where it takes a while for the market to actually adopt, and adapt to the use of, the innovation. A famous example of this phenomenon is the heavy ICT investment in America during the 1970s and 80s, which lead to what Solow (1987, p 36) termed the "productivity paradox" in which he claimed that "you can see the computer age everywhere but in the productivity statistics." However, almost as soon as Solow had uttered these words the "paradox" seemed to be resolved. Indeed for instance David (1990) pointed out that the long productivity lag of the ICT revolution may not be all that surprising as there had in fact been much of the same type of lag during the transition from steam to electricity, and by the time David published his now famous paper the computers could indeed be seen everywhere, including in the productivity statistics. History has indeed then seen productivity paradoxes before, but even so, and even if Sweden could be deemed as being – or having been – a paradox perhaps the problem more so lies in the expectation of the effects of R&D being set too high in the first place, a point driven home by Ejermo, Kander and Schön (2007). Moreover it should be highlighted that even if we assume that R&D would have a strong effect on growth, increased GERD need not mean increased productivity. One could for instance imagine that increasing the R&D expenditure may not always lead to more researchers, but could rather result in higher salaries for the existing researchers, which need not mean that there would be neither a higher level of output nor that the researches would become more productive due to the pay raise.

3.5 The Swedish R&D Paradox

The so called Swedish R&D Paradox is a phenomenon that has received considerable attention based on the paradigm that high levels of R&D expenditure (investment) *should* result in high levels of GDP growth. The paradox discussion stems from an argument that Sweden has not followed this path, and has in spite of having one of the highest R&D intensities in the world, not shown impressive GDP growth rates. One of the main reasons why I have decided to perform research on this topic is because it seems as if almost everyone, whether in academia or not, seems to agree with the “fact” that there exists such thing as a Swedish Paradox, yet there are many – and rather diverging – explanations for its occurrence. The most common explanations that are given are: firstly, that Sweden’s expenditure on higher education is too high in comparison to the output that this sector produces, a phenomenon analysed and confirmed predominantly by Magnus Henrekson (Henrekson and Rosenberg 2001; Andersson, Asplund and Henrekson 2002; Goldfarb and Henreksson 2003). If this were true it would imply either that the knowledge that academic research produces has a very low commercial value or that Swedish R&D in the higher education sector is highly inefficient. This higher education hypothesis is nonetheless contrasted by Jacobsson and Rickne (2004) who argue that this paradox might indeed largely stem from accounting differences where for instance Sweden pays salaries even to its foreign PhD candidates, which countries such as for instance Britain typically do not do. On the other hand the Swedish PhD candidates’ results are typically also published in English, where this might not be as common in for instance France or Italy, consequently creating an overestimation of both the input and output of the Swedish higher education sector. Due to this twofold overestimation the argument made by Jacobsson and Rickne (2004) nonetheless largely fails to refute the higher education hypothesis as an increase of both inputs and outputs would keep the relative relationship largely stable. However, also worth mentioning when it comes to the high spending on what could be seen as developing the knowledge base through basic research is that, if Romer (1990) was right in asserting that innovations stem from old knowledge, then the Swedish innovativeness ought to in the long run benefit from these types of investments. The second prominent explanation has to do with the Swedish high-tech industry, which even though seen as relatively productive, is far too concentrated to a few firms. A phenomenon that, according to by Braunerhjelm (1998), leads to low levels of *positive spillovers* both within this industry and from this industry to other sectors of the economy. The third explanation is that even though Swedes are relatively good at *inventing* their inventiveness is unfortunately also coupled by a relatively dire ability to *innovate*. This then essentially implies that there is a lack of entrepreneurial ability in Sweden, or that there is a lack of links between the research that has been undertaken in for instance the higher education sector and the industries that could turn these inventions into innovations; a point of view that can capitalize on a common lacking link in both the first and second mentioned hypotheses. This third hypothesis of a lacking entrepreneurial ability or “E-factor” as Acs et al. (2005; 2010) according to Ejermo et al. (2007), call it[10] is for instance explored by Ejermo and Kander (2005) who come to the conclusion that a potential paradox may stem from Sweden lacking entrepreneurial ability, but that the paradox may also be attributed to a low skill premium that makes it relatively cheap to invent in Sweden, while relatively expensive to produce the goods stemming from these inventions. Consequently, since it is relatively inexpensive to perform R&D in Sweden but relatively expensive to produce the goods in Sweden due to the low skill premium – or if one prefers, an egalitarian social structure – firms may choose to perform their research in Sweden whilst production while placing the production in a country where non-skilled labour is cheaper. In effect this would not render a positive effect upon the growth rate if the profits from the production are not reverted back to Sweden. However, as much as this may have an effect on the Swedish output it also reflects a rational specialisation in the global division of labour, and as such this type of behaviour – even if thought of as less than socially optimal for Sweden – is fully in line with the doctrine that firms are rational profit maximizers. In instances when production is not moved abroad a lack of entrepreneurs may also result in either a patent being sold to a foreign firm or simply never commercialized.

The above mentioned explanations could of course all be valid, and the existence of one need not preclude the existence of the others. That said, the basic concept that there even exists such a phenomenon as a Swedish R&D Paradox stems from the relationship between R&D expenditure and GDP growth, typically measured in the aggregate, which of course creates speculations as to where the paradox – if such a thing can even be measured using this relationship – stems from. However, as it is my intention to explore *if* we can even talk about a Swedish paradox in the first place, this paper will not deal with the cause of the Paradox, if such a paradox can even be found, but rather what basis we have for assuming that R&D expenditure in fact increases growth and how well the R&D intensity can indeed reflect this

[10] Acs et al. (2010) talk about the entrepreneurial factor; however it ought to be mentioned that I have not fund the term “E-factor” to be their own words but prescribed to them by Ejermo, Kander and Schön in their 2007 paper. It is nonetheless possible that this term does appear in the version of the paper given at the Uddevalla Symposium in 2005, which Ejermo et al. use. This matters little for the argument per se; however, the footnote has nevertheless been added for the sake of clear composition.

relationship. Moreover, as the assumption of the existence of a Swedish paradox is argued to exist not only on a sectoral level, but that whatever the reasons for the paradox might be are so strong that they shine through in the aggregate, the empirical sections of this paper will deal with the aggregate only. Besides, it could be argued, as Griliches (1991) does, that aggregation of the data may in fact be needed to properly gauge the effect of R&D investments upon growth. The need for aggregation, according to Grilches, largely stems from potential spillovers that may occur from one industry to another, and that these spillovers may be "lost" if aggregation of the data does not take place. In other words then, R&D that takes place in one industry may have an effect on several other industries and consequently the various sectors of the economy need to be aggregated in order for us to be able to more accurately observe the effects of R&D activities. Consequently, as pointed out before, this paper aims to empirically explore the GERD / GDP relationship on which the supposed paradox is based, *not* where such a paradox may stem from, if it were indeed to exist.

4 Empirical Investigation

No macroeconomic magnitude is more important for the future evolution of the economy than productivity growth, and none is harder to predict. – Robert J. Gordon

4.1 Data

This section outlines the sources, span, usage as well as the limitations of the data used in the empirical investigation of the GDP / GERD relationship. The information in this section is of key importance to understanding the comparability of different data series of the empirical investigation and why some countries unfortunately, due to data constraints, have had to have been left out of a number of empirical analyses.

4.1.1 Sources and span

For the sake of cross-country comparability all of the primary data has been collected from the Eurostat database, and all values are reported in Euros, including non-Euro countries such as Sweden and the United States. Calculations concerning real GDP are based on GDP in millions of euro, chain-linked volumes, with 2000 as a reference year (at 2000 exchange rates). Calculations concerning real GERD are based on GERD in millions of PPS at 2000 prices. For R&D Intensity calculations both GERD and GDP have been collected in volumes that have not been adjusted for inflation – millions of euro (from 1.1.1999) and millions of ECU (up to 31.12.1998) – as it is common practice to calculate the R&D intensities based on nominal values. Moreover all data, unless otherwise specified, is in the form of annual values.

In cases where there has been a one year break in the series the value of the previous year has been used as a proxy. In cases of two-year breaks in the series the previous year's value has been used in the first instance and the preceding year's value in the second. This procedure has *only* been utilized in the descriptive section as well as in the first explorative analysis where a one year break in the series cannot be deemed as having a large effect on the outcome. However in the correlation and regression estimates no extrapolation or interpolation has been used as to not superimpose linearity onto the series and create spurious results, in these instances the series that have breaks in them have instead been dropped.

4.1.2 Data usage

Since it is the intention of the paper to let the data speak for itself, the descriptive as well as the explorative sections have been conducted using a positive approach with as little normative i.e. value based, input as possible. This has been done under the assumption, outlined by Remenyi et al (1998),[11] that I as a researcher while conducting this research is independent from the subject, i.e. I am affecting neither the subject, nor it does it affect me. It is nevertheless likely that there is some form of researches bias reflected even in these sections – perhaps especially in the explorative section – as for instance the control variables in the regressions are based on findings from the literature review and my own views of their suitability for potentially having an effect upon the GERD / GDP relationship. The control variables, which have also been collected from Eurostsat, consequently reflect the variables that have been regarded by other researchers as well as by me as being the most apt in trying to unveil the relationship between R&D expenditure and growth (or lack thereof). However, as it is ultimately *I* who have chosen which of these variables to include it is of course possible that they reflect my own predisposed views on their abilities to affect growth. Put in this context it would perhaps then be more appropriate to say that this chapter, using the definitions given by Saunders et al. (2007, p. 105), straddle a gray line that divides the *direct realist* from the *critical realist*, where I in the descriptive section report the relationship "as it is" whilst I in the explorative section perhaps more so depict the relationship based on how I "perceive it to be." However, the latter should not be equated with how I believe that "it ought to be" which from my point of view would be far more value based.

4.1.3 Data limitations

For many of the EU countries there exists quite good data on R&D covering the 21st century, however as reported by Eurostat some countries may potentially be over- or under-

[11] Remenyi et al., 1998, p. 33; quoted in Saunders et al. p. 103.

estimated.[12] Even though Swedish R&D data is very rigorous when it comes to its breadth and depth, the data has traditionally only been collected and complied bi-annually. I presume that this is the main reason why longitudinal cross-country analyses of R&D related performance tend to exclude Sweden, in fact I have not been able to find a single study in which longitudinal data on Sweden has been used (apart from its use in descriptive statistics where either linear interpolation has been used, or where the R&D expenditure has been assumed to be the same as the previous year for which data was collected.) This of course creates a problem, not in the analysis of the general correlation or causality, but on the applicability of the results from the explorative section on the Swedish case as Sweden unfortunately will not be included in some of these analyses. This however need not be a problem if Sweden can be deemed as not being significantly different from the other EU countries, or a part thereof such as the other high income OECD countries. If Sweden could nonetheless be deemed as significantly different from the other high income OECD countries within the European Union, then this approach would only allow me to generalize about the general causality but may not result in very significant results for Sweden in particular. However, I have chosen this approach as the only other viable alternative would be to interpolate the data points of the Swedish series, which I fear could cause spurious results. Even though the use of this method may, as previously alluded to, somewhat limit what can be said about the Swedish case in particular, it does not necessarily have any significant effects upon the exploration of the GERD / GDP relationship in general. Moreover, as it is the general that pattern that needs to be investigated in order to even allow for a discussion of the existence of a paradox I believe that these limitations do not largely affect the outcome of the overarching analysis.

4.2 Descriptive Statistics

This section more or less serves as a visual depiction of the changes of real GERD and real GDP, both in absolute terms as in well as in percentage form, over time. Furthermore the R&D intensities are included under the same premises. Conclusions in this section consequently do not span further than the patterns that can be deduced from visual inspections of the data, i.e. what can be seen in the figures and tables. It is not the intention of this section to estimate or explain the relationship between the variables, but is more so in place to create the base for the empirical investigations in the ensuing explorative section.

[12] This study will not report the potential over- and under- estimated values as this would take up far too much space, however the flagged values can be found in the original datasets at Eurostat.ec.europa.eu. Last accessed on May 24, 2010.

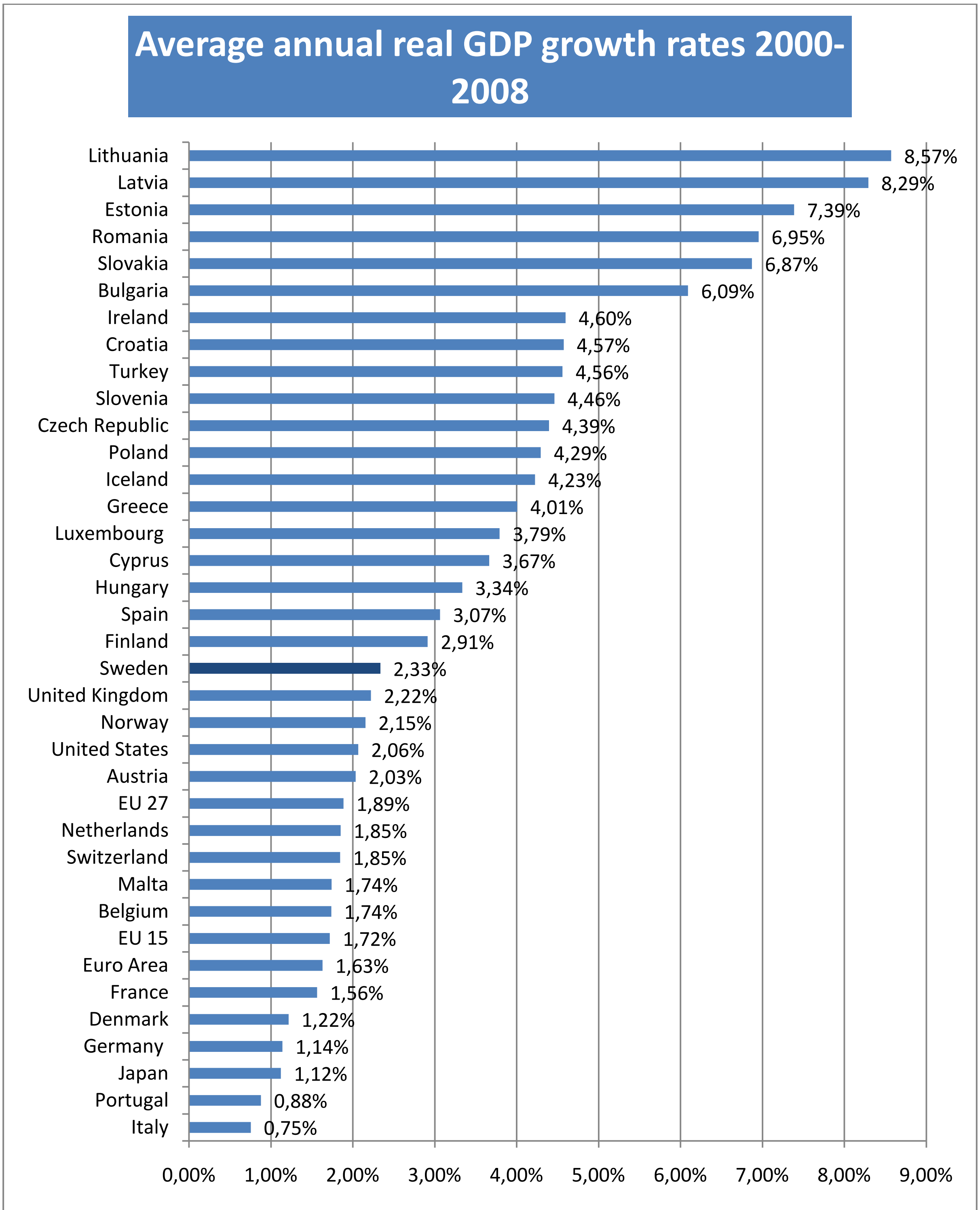
4.2.1 Computation of R&D intensities and averages

The R&D intensity is, as previously asserted, the ratio of GERD to GDP. In other words it displays GERD as a percentage of GDP. However, two things ought to be mentioned prior to reviewing the actual data. Firstly, as mentioned in the data section the R&D intensities are reported in nominal values; however, when talking about the growth of GDP and GERD this refers to their *real* values as to facilitate long term comparisons. It should consequently be noted that the R&D intensity does not add up to the ratio of real GERD and real GDP. Furthermore, since nominal growth need not mean that there is real growth, and since real growth is what increases the living standard of the people in the economy, it is more appropriate to talk about economic growth in real terms. Secondly it should be pointed out that the EU 15, EU 27 and Euro Area (16 countries) averages that are reported in this paper do not, unless otherwise stated, reflect their arithmetic averages, i.e. the total percentage growth of all countries within that category over the number of countries in the same category, but take into account the relative size of the individual economies. Consequently economies such as Germany and France have a far greater effect on for instance the EU 27 average than for example Latvia or Lithuania do.

4.2.2 A comparison of international growth rates

Based on the average real growth rates, displayed in figure 2, it seems less than obvious to talk about a Swedish paradox, at least in the 21st century. As can be seen Sweden in fact displays one of the highest average growth rates of the EU 15 countries over the 2000-2008 period, indeed outperforming both the US and the EU 15 averages. As such, how is it that we still today talk about the existence of such a thing as a Swedish paradox? In fact, it was a figure such as the one below that got me to question the existence of a Swedish R&D Paradox in the first place.

Figure 2 – Average annual real GDP growth rates 2000-2008



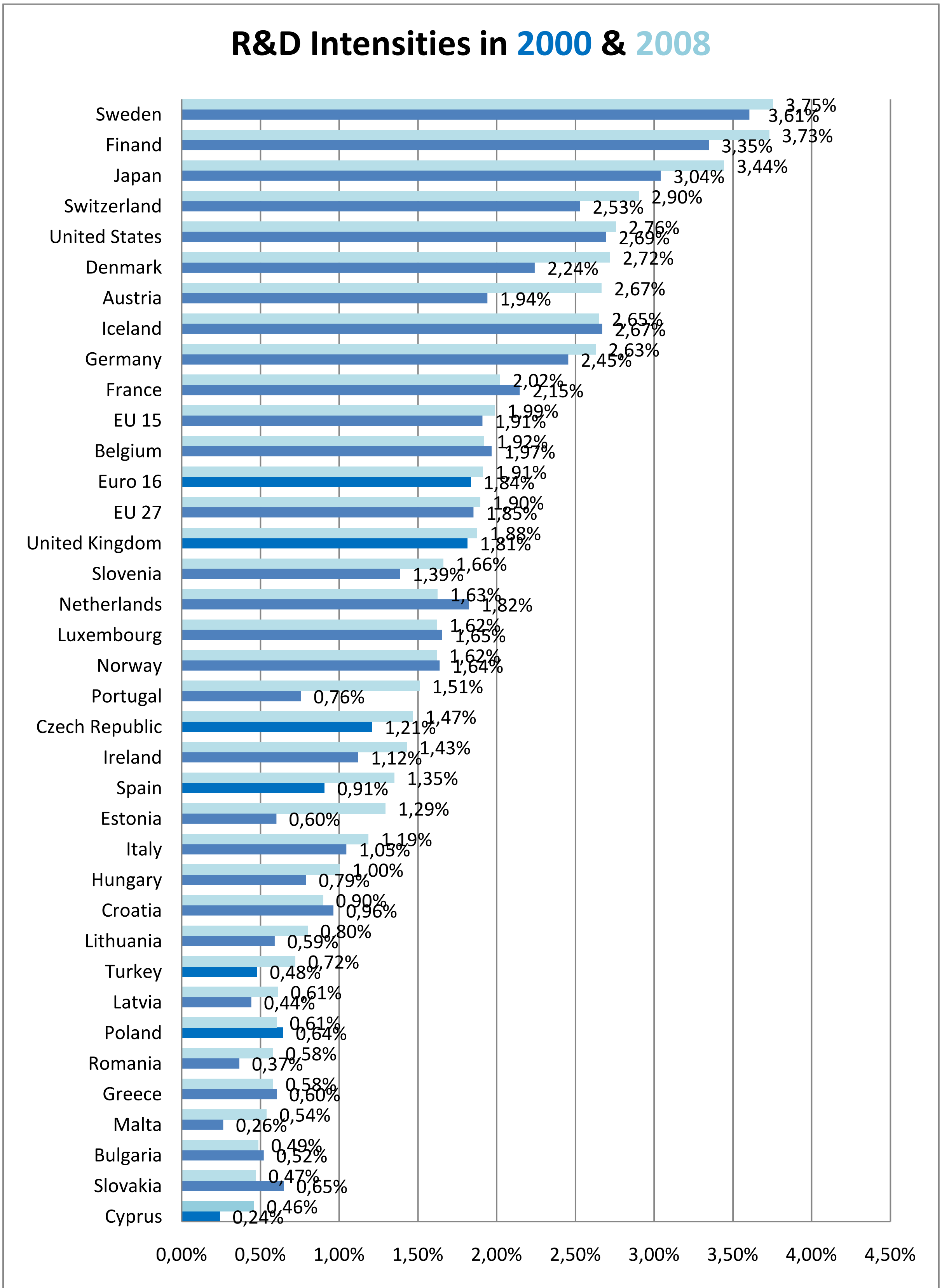
Based on data from Eurostat.

As can be seen in figure 2 Sweden's average growth rate is by no means very high; however, compared to the other big R&D spenders such as the United States, Japan and Denmark it performs rather well. In all actuality, out of the big spenders – based on the intensities reported in figure 3 – only Finland outperforms Sweden during the first 8 years of the 21st century in terms of GDP growth.

4.2.3 International R&D intensity comparison

As can be understood from figure 3 below Sweden has during the 21st century had very high R&D intensity levels, indeed it was the EU (if not world) leader in both 2000 and 2008. That said Finland saw a higher intensity growth during this period, especially post 2004, and was in 2008 at almost the same R&D intensity level as Sweden. Consequently, holding everything else constant it would be logical that *if there were a strong relationship* in general between the R&D intensity and the growth, that Sweden and Finland would be at approximately the same growth rate in 2008. However such a close link between the intensity and the growth rate would further imply that Finland should have experienced lower levels of growth in previous periods, albeit increasing at a faster pace due to the increasing R&D intensity. Figure 3 reflects that Sweden undoubtedly has exhibited an extremely high R&D intensity compared to *most* other countries, developed or not. However following the logic that increases of the R&D intensity would contribute to faster increases of the growth rate, then countries who exhibit high but rather stable R&D intensities ought to reflect high but relatively stable GDP growth rates as well. Following the same logic the countries that show the fastest increase in the growth rate of GDP should arguably be correlated to the countries whose R&D intensities and GERD have also increased the most, not those who display high, but stable, R&D intensities. This relationship seems to hold in some cases; looking at Sweden and Finland for instance we can deduce that both show GDP growth rates considerably above the EU 15 average, and both display R&D intensity levels that are far above the EU 15 average. Finland has nonetheless shown a faster increase in the GDP growth rate than Sweden during the 2000-2008 period, which would be in line with the previous reasoning. If we on the other hand look at for instance Estonia, Malta and Portugal – who have all roughly doubled their R&D intensities over the same period – only Estonia has exhibited impressive GDP growth rates, which seems to lend little support for the suggested close link between the R&D intensity and economic growth, at least in the short run.

Figure 3 – R&D Intensities in 2000 & 2008



Calculated based on data from Eurostat.

Notes: No data available for Croatia and Malta prior to 2002 – 2002 has been used as a proxy for 2000. No data available for Switzerland post 2004. Previous year used as proxy: Greece 2000, 2008; Sweden 2000; Luxembourg 2001, Turkey 2008; Norway 2000; Japan 2008.

4.2.4 The descriptive correlation between changes in GERD, GDP and the R&D intensity

As the real GDP growth rate seems to on average be rather poorly mirrored by the R&D intensity let us compare the real GDP growth rates during the 21st century in comparison to the growth of R&D intensity and the real GERD growth as to see whether or not an obvious relationship may be detected when all three variables are taken into consideration. Table 1 compares the countries' R&D intensity growth to the growth in Real GDP and Real GERD from 2000 to 2008, where the countries have been ranked from high to low according to their cumulative percentage growth in R&D intensity.

Table 1 – 21st century R&D Intensity, Real GERD and Real GDP developments

21st century comparison of R&D Intensity, Real GERD and Real GDP developments									
	R&D Intensity			Real GERD			Real GDP		
Country/ Area	R&D 2000	R&D 2008	R&D Change	GERD 2000	GERD 2008	GERD Change	GDP 2000	GDP 2008	GDP Change
Estonia	0.60%	1.29%	**115.30%**	70.763	253.702	**258.52%**	6159.8	10255	**66.48%**
Malta	0.26%	0.54%	**104.58%**	16.573	38.868	**134.53%**	4221.1	4882	**15.66%**
Portugal	0.76%	1.51%	**99.24%**	1151.852	2477.713	**115.11%**	122269.9	131938.2	**7.91%**
Cyprus	0.24%	0.46%	**89.02%**	28.543	71.764	**151.42%**	10078.7	13403.3	**32.99%**
Romania	0.37%	0.58%	**58.35%**	407.289	1048.487	**157.43%**	40651.3	66088.5	**62.57%**
Turkey	0.48%	0.72%	**50.79%**	2455.72	5176.669	**110.80%**	289932.8	408919.9	**41.04%**
Spain	0.91%	1.35%	**48.84%**	6776.095	12864.709	**89.85%**	630263	804121.9	**27.59%**
Latvia	0.44%	0.61%	**38.38%**	73.307	177.116	**141.61%**	8495.6	14835.6	**74.63%**
Austria	1.94%	2.67%	**37.37%**	3892.322	6325.946	**62.52%**	207528.8	245513.1	**18.30%**
Lithuania	0.59%	0.80%	**35.64%**	154.748	371.928	**140.34%**	12377.3	21925.8	**77.15%**
Ireland	1.12%	1.43%	**27.49%**	1063.307	1916.094	**80.20%**	104830.2	148198.3	**41.37%**
Hungary	0.79%	1.00%	**27.09%**	849.647	1403.693	**65.21%**	51320.2	66727.7	**30.02%**
Denmark	2.24%	2.72%	**21.32%**	3000.492	4039.564	**34.63%**	173597.9	192585.4	**10.94%**
Czech Republic	1.21%	1.47%	**21.23%**	1620.974	2741.181	**69.11%**	61495.2	85818	**39.55%**
Slovenia	1.39%	1.66%	**19.76%**	419.371	703.776	**67.82%**	21434.8	30039.3	**40.14%**
Switzerland	2.53%	2.90%	**14.75%**	5015.081	5980.892	**19.26%**	270917.7	315925.4	**16.61%**
Italy	1.05%	1.19%	**13.32%**	13263.173	16059.31	**21.08%**	1191057.3	1271958.4	**6.79%**
Japan	3.04%	3.44%	**13.20%**	86020.369	108479.38	**26.11%**	5058005.4	5569123.4	**10.11%**
Finland	3.35%	3.73%	**11.44%**	3866.492	5441.206	**40.73%**	132110	166760	**26.23%**
Germany	2.45%	2.63%	**7.13%**	45532.968	53809.038	**18.18%**	2062500	2274112.5	**10.26%**
Euro 16	1.84%	1.91%	**4.20%**	118603.758	145902.282	**23.02%**	6779802.2	7773947.3	**14.66%**
EU 15	1.91%	1.99%	**4.13%**	153364.637	188545.196	**22.94%**	8764298	10120625.3	**15.48%**
Sweden	3.61%	3.75%	**4.11%**	9027.107	9727.151	**7.75%**	266422	322401.6	**21.01%**

United Kingdom	1.81%	1.88%	**3.46%**	24231.334	30083.42	**24.15%**	1602239.6	1922459.7	**19.99%**
United States	2.69%	2.76%	**2.31%**	233213.59	282890.596	**21.30%**	10774686	12777015.4	**18.58%**
EU 27	1.85%	1.90%	**2.29%**	159830.615	199029.161	**24.53%**	9201979.2	10763536	**16.97%**
Iceland	2.67%	2.65%	**-0.68%**	188.273	257.715	**36.88%**	9420.6	13003	**38.03%**
Norway	1.64%	1.62%	**-1.19%**	2290.104	2727.553	**19.10%**	182578.5	217957.8	**19.38%**
Luxembourg	1.65%	1.62%	**-1.97%**	336.776	442.945	**31.53%**	22000.6	29510.1	**34.13%**
Belgium	1.97%	1.92%	**-2.39%**	4845.951	5468.837	**12.85%**	252216	291634.9	**15.63%**
Greece	0.60%	0.58%	**-3.91%**	1008.644	1350.32	**33.87%**	137929.5	187670.6	**36.06%**
France	2.15%	2.02%	**-5.86%**	28669.766	30787.685	**7.39%**	1441372	1644385.5	**14.08%**
Poland	0.64%	0.61%	**-6.03%**	2265.796	2952.635	**30.31%**	185713.8	257483.1	**38.65%**
Bulgaria	0.52%	0.49%	**-6.19%**	224.861	326.577	**45.24%**	13704.3	21218.6	**54.83%**
Croatia	0.96%	0.90%	**-6.74%**	440.131	528.948	**20.18%**	23117.3	32633.3	**41.16%**
Netherlands	1.82%	1.63%	**-10.91%**	7431.3	7724.141	**3.94%**	417960	487644	**16.67%**
Slovakia	0.65%	0.47%	**-27.41%**	334.262	392.812	**17.52%**	22029	35652.7	**61.84%**

Calculated based on data from Eurostat.

Notes: R&D Intensity and GERD: No data available for Malta and Croatia prior to 2002. No data available for Switzerland post 2004. Previous year used as proxy: Greece 2000, 2008; Sweden 2000; Luxembourg 2001, Turkey 2008; Norway 2000; Japan 2008.

Table 1 arguably shows no uniform pattern of GDP growth based on the growth in R&D intensity, indeed it shows little pattern of any kind. In fact the countries with the third and fifth highest GDP growths, Estonia and Slovakia respectively, can be found at the top and bottom of the R&D intensity growth ranking. Moreover, one can for instance notice how Malta and Portugal have experienced lower GDP growth than Sweden whilst roughly doubling their R&D intensities and increased their real GERD by 134.53% and 115.11% respectively compared to Sweden who increased its R&D intensity by less than a twentieth and its real GERD by 7.75% during the same period. This could point toward the general relationship between GERD and GDP being weak, and consequently that the R&D intensity would be a rather poor forecaster of economic growth. However it could also reflect that there is a lagged effect of GERD upon GDP that is not fully captured in this comparison. Notable is also that Sweden clearly does not underperform compared to the others when it comes to growth in GDP compared to growth in both R&D intensity and GERD; which would then in fact perhaps suggest that Sweden, at least at the margin, in reality gets more out of its R&D expenditure than most other countries do. Unless this is indeed as previously mentioned the payoff from R&D expenditures in previous periods, i.e. that the effect of R&D activities shows up with a considerable time lag. In all actuality then, as can be understood from a close examination of table 1 only Slovakia outperformed Sweden as far as the growth ratio between real GERD and real GDP is concerned, and it did so while showing a decrease in its R&D intensity from .65 to .47 % compared to Sweden's increase from 3.61 to 3.75 %, once again lending little support to the R&D intensity being a good measure of the potential for economic growth.

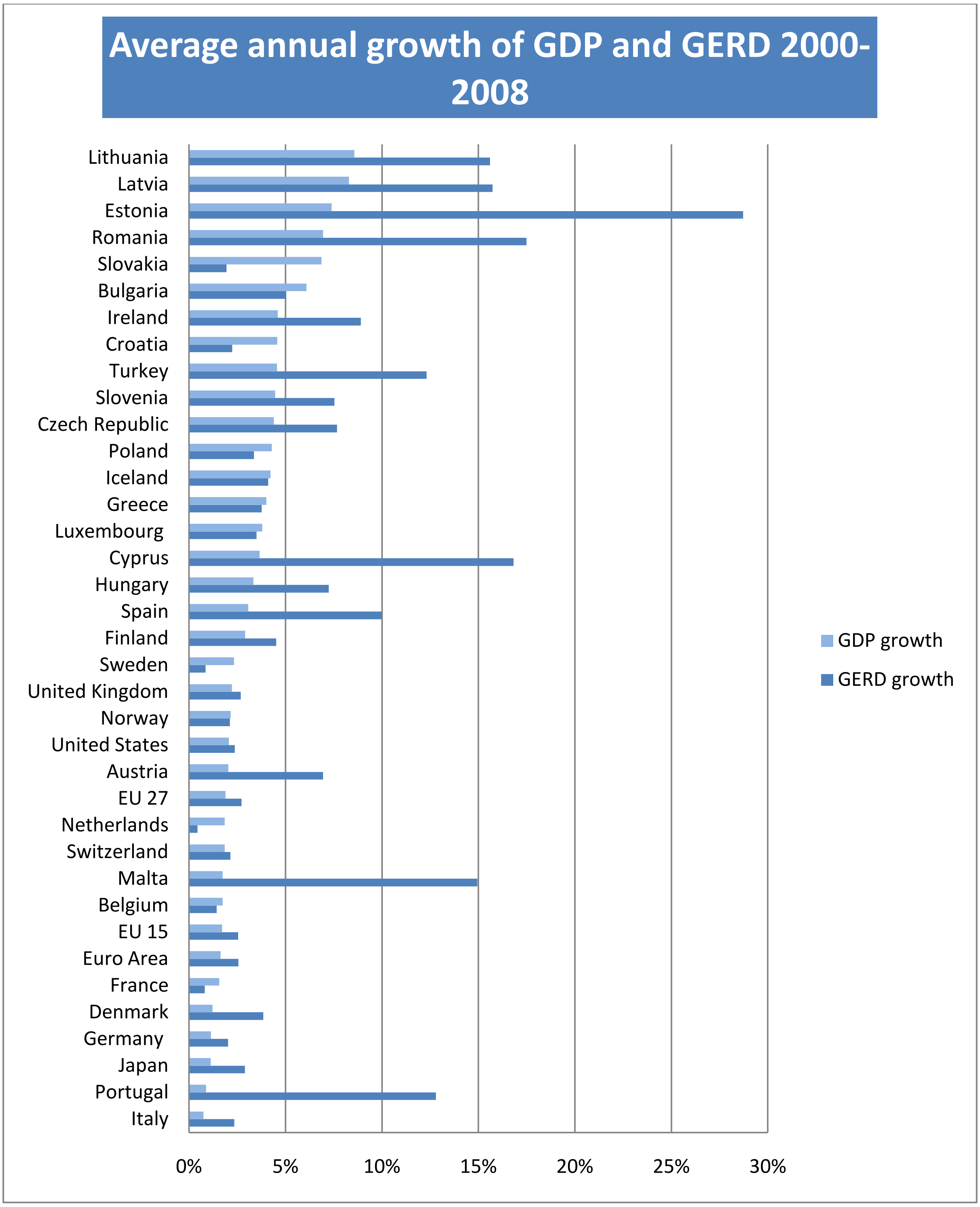
Even though finding convincing patterns in the data may be hard, there ought to theoretically be a more descriptive pattern between the changes in GDP and the changes in the R&D intensity as the former is indeed the denominator in the R&D intensity calculation. Consequently even if such a pattern could be detected it should therefore not be seen as all that extraordinary. Be that as it may, there may of course sometimes also be the case that a large GERD growth can be precluded in the R&D intensity measure if coupled by a large GDP growth as the intensity is calculated based on their absolute levels, not their percentage changes. If we for instance look at Greece and Bulgaria we can see that they have indeed faced rather substantial increases of their R&D expenditures, yet we find that both these countries indeed show a negative growth of their R&D intensities during the same period; exhibiting how, at least in the short term, the R&D intensity may not always reflect the developments of all that well GERD if these developments are coupled by substantial changes in GDP. Moreover, table 1 also helps explain why for instance, Estonia and Slovakia who rank third and fifth highest in terms of average annual GDP growth rates, have shown very different developments of their R&D intensities; indeed while Slovakia displayed a large decrease of the intensity Estonia more than doubled its intensity. However as can be seen from the above table Estonia increased it GERD by a whopping 258.52% whilst Slovakia only increased its GERD by 17.52% and as such even though changes in GDP growth may preclude the changes of GERD in the R&D intensity, the GDP growth need not always distort the relationship *between the countries* by all that much.

Based on a visual inspection of the above figure there nevertheless seems to be a low general correlation between the growth in GERD and the growth in GDP. However, it is nonetheless also true that the top four performers, in terms of total GDP growth, are also countries that have considerably increased their R&D expenditures. However as such patterns may be hard to deduce from table 1, as it is indeed somewhat "overloaded" with a vast amount of variables, another figure has been added to conclude the discussion of the short term descriptive correlation between real GDP and real GERD.[13] As such, figure 4 below

[13] Table 1 may indeed be rather "messy" to look at; I nonetheless feel that it was necessary to present all of the variables in their absolute levels as well as their percentage changes to fully qualify the reasoning behind some of the pitfalls of the R&D intensity measure.

displays the percentage average growth rates of real GERD and real GDP over the 2000-2008 period; however I feel little need to try to explain their potential relationship in the short term much further.

Figure 4 – Average annual growth of GDP and GERD 2000-2008



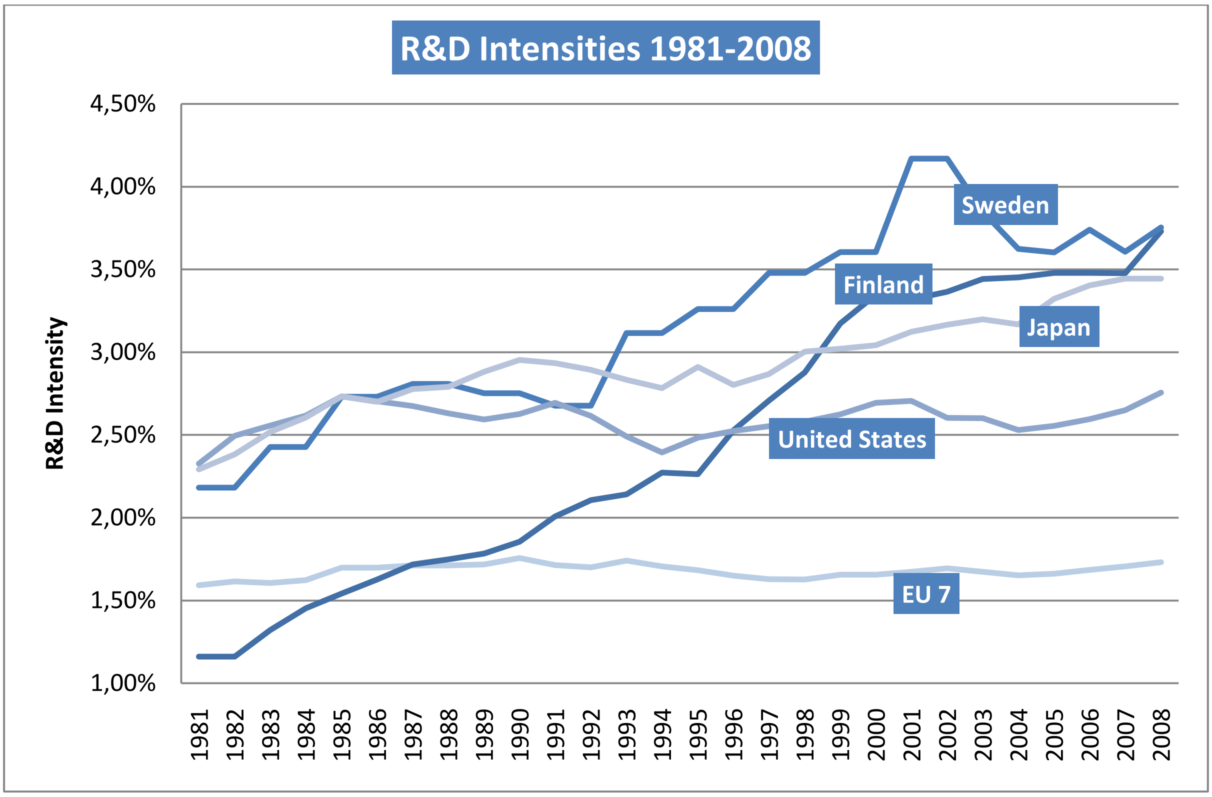
Calculated based on data from Eurostat.

Notes: GERD: No data available for Malta and Croatia prior to 2002. No data available for Switzerland post 2004. Previous year used as proxy: Greece 2000, 2008; Sweden 2000; Luxembourg 2001, Turkey 2008; Norway 2000; Japan 2008.

4.2.5 Long term developments

As it has been hard to distinguish any descriptive pattern in the relationship between the R&D intensity and real GERD as compared to real GDP growth in the short term, can such a pattern be found in the longer term? As already pointed out there is a chance that there might be a long lag of the effect of R&D expenditure upon economic growth, consequently the following graphs and tables show their developments in the longer term. Figure 5 below shows the long term development of R&D intensities for Sweden, Finland, and "EU 7" as a proxy for the EU 15 less Sweden and Finland.[14] Moreover, the United States and Japan have been added as they can be considered as some of the world leading economies in terms of R&D expenditure, technology developments as well as output.

Figure 5 – R&D Intensities 1981-2008



Calculated based on data from Eurostat.

Notes: No data for Denmark 1994; United Kingdom 1982, 1984; Finland 1982; Sweden 1982, 1984, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000 and 2002.

[14] Due to data constraints reliable long term series are only available for 9 of the EU 15 countries: Austria, Denmark, Finland, France, Italy, the Netherlands, Spain, Sweden, and the United Kingdom. Sweden and Finland have been removed from this group as to contrast their performances to the others; consequently, this group has been labelled the EU 7.

Based on figure 5 it is clear that Sweden and Finland were significantly above the other developed EU economies as well as the United States in 2008 in terms of R&D intensity and had been so at least since the mid 90s. However, the figure also depicts how Japan's R&D intensity is not far behind those of Sweden and Finland. Moreover it shows that Finland has clearly had the highest growth in R&D intensity during the 1981-2008 period, whilst the EU 7 and the United States have shown roughly stable R&D intensities. However would this consequently reflect lower or more stable GDP growth for the latter two in comparison to the preceding three? Table 2 takes a closer look at their individual performances – as far as R&D intensity, real GERD and real GDP are concerned – over the same period.

Table 2 – Long term comparison of the developments of R&D Intensity, Real GERD and Real GDP

Long term comparison of R&D Intensity, Real GERD and Real GDP developments

	R&D Intensity			Real GERD			Real GDP		
Country/ Area	R&D 1981	R&D 2008	R&D Change	GERD 1981	GERD 2008	GERD Change	GDP 1981	GDP 2008	GDP Change
Finland	1.16%	3.73%	**221.16%**	820.479	5441.2	**563.17%**	80757	166760	**106.50%**
Sweden	2.18%	3.75%	**72.06%**	3078.335	9727.2	**215.99%**	175583.6	322401.6	**83.62%**
EU 7	1.59%	1.73%	**8.62%**	7222.291	15412.1	**113.40%**	503749.5	938381.1	**86.28%**
United States	2.33%	2.76%	**18.48%**	107433.157	282890.6	**163.32%**	5746499.2	12777015.4	**122.34%**
Japan	2.29%	3.44%	**50.31%**	38166.438	108479.4	**184.23%**	2978314.1	5569123.4	**86.99%**

Calculated based on data from Eurostat.

Notes: R&D Intensity and GERD: No data for Denmark 1994; United Kingdom 1982, 1984; Finland 1982; Sweden 1982, 1984, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000 and 2002. The EU 7 values refer to the arithmetic averages of Austria, Denmark, France, Italy, the Netherlands, Spain, and the United Kingdom.

Based on table 2 above one can see somewhat of a descriptive pattern where Finland, Japan and Sweden – the countries who have had the highest growth in R&D intensities – have also exhibited far higher GERD / GDP ratios in *real terms*. It is nevertheless interesting that for instance the United States who initially was at approximately the same R&D intensity level as Japan grew almost a third more than Japan did, in spite of having experienced a lower increase in its real GERD. Also by looking at the variables in table 2 it seems as if Sweden has had a lower return to R&D investments than the EU 7, United States and Japan have, which would certainly be in line with the existence of a Swedish R&D paradox; however, it seems to outperform Finland in terms of its change in real GDP both in terms of its change in real GERD and its change in R&D intensity. Consequently, if this indeed is the case then why are we talking about a Swedish R&D Paradox and not a Finnish one? That said, by comparing the variables in table 2 to the equivalent variables in table 1 it however seems as if the R&D intensity may indeed be a better forecaster of growth in the long run than it is in the shorter run. Accordingly its forecasting abilities in the extreme short run, for instance annually, ought to be even worse. With that in mind, one should perhaps be a bit weary of drawing policy conclusions about how an increased R&D intensity would increase growth, particularly in the shorter term.

4.3 Explorative Statistics

This section will encompass three rather simple statistical analyses that aim to statistically test the relationship between real GDP and real GERD and/or the R&D intensity within the European Union. In the first instance high growth countries will be pitted against low growth countries as to see whether high growth countries indeed exhibit higher R&D intensities. The second exercise explores the correlation between real GDP growth and real GERD growth as to see if there exists a correlation between the two variables, as such a correlation *could* imply a causal relationship, this analysis will subsequently also set the stage for the last exercise which will estimate the effect of the change in GERD upon the change in GDP during the 21st century through a series of linear multivariate regressions.[15]

4.3.1 A comparison of the R&D intensity of high and low growth countries

Since it has so far been hard to see any clear pattern in the effect of high or low R&D intensities upon the growth rates the countries have been divided into two groups, a group of high- and a group of low- growth countries respectively, as to see whether the countries that on average demonstrate higher growth rates also exhibit higher R&D intensities. The countries have been divided into either of these two categories based on their cumulative growth during the 2000-2008 period as compared to the median. This analysis has been carried out for both the EU 27 and the EU 15, as it would perhaps be logical for less

[15] A fourth analysis was furthermore carried out, which estimated a similar model to that used in section 4.3.3.1 but which served to test the forecasting ability of the changes in GERD upon the changes in GDP. This model was tested with a five year lag structure as to see whether the changes in the R&D spending at *t-1*,..., *t-5* could help forecast the changes in GDP at time *t* in a group of high income EU members. The five year lag structure was chosen under the assumption that it would consequently encompass what Carson, Grimm, and Moyland (1994, p. 44) refer to as potential gestation and application lags. Where the gestation lag refers to the time it takes to develop a product from the initial point of investment to the time the product is finished, a period of one to two years; while the application lag refers to the lag between the end of the development of the product to its introduction on the market, which amounts to a few months up to two years. Furthermore, as it may be reasonable to assume that it would take an innovation, i.e. commercialized R&D output, a year or so to show up in profits another year was added resulting in a five year lag structure. However, the results from these test where unfortunately largely statistically insignificant with extremely low R^2s throughout (~.12 to .17), consequently, as kindly suggested by my supervisor, these results will not be presented in this paper.

developed countries to face higher growth irrespective of their R&D intensities as they could - as previously noted – be argued to be on a catch-up path. In both cases, EU 27 and EU 15, the median country has been dropped, which corresponds to Hungary and Austria, for the EU 27 and the EU 15 respectively. As pointed out in section 4.1.1, series with a one year break use previous year's value as a proxy for the missing data point; and where there has been a two year break in the series the first has been filled with previous year's data and the second with the successive year's data, e.g. in the case of Luxembourg there is a break in the series for 2001 and 2002, consequently 2001 has taken on the value of 2000, and 2002 the value of 2003 – please see "notes" for details on where proxies have been used.

Table 3 – EU 27 R&D Intensities of low vs. high growth countries

EU 27 R&D Intensities of low vs. high growth countries		
Average R&D Intensities 2000-2008		
Year	**Low growth group**	**High growth group**
2000	1.871%	0.772%
2001	1.949%	0.784%
2002	1.961%	0.777%
2003	1.949%	0.775%
2004	1.943%	0.801%
2005	1.963%	0.836%
2006	2.011%	0.895%
2007	2.032%	0.878%
2008	2.118%	0.928%
	Mean	**Mean**
	1.977%	0.827%
	Variance	**Variance**
	0.892	0.186
t-value 23.864****		

Calculated based on data from Eurostat.

Notes: High growth countries: Cyprus, Luxembourg, Greece, Poland, Czech Republic, Slovenia, Ireland, Bulgaria, Slovakia, Romania, Estonia, Latvia and Lithuania. Low growth countries: Italy, Portugal, Germany, Denmark, France, Belgium, Malta, the Netherlands, Austria, United Kingdom, Sweden, Finland and Spain. Proxies where the previous year's value has been used: Luxembourg 2001; Greece 2000, 2002, 2008; Sweden 2000, 2002. Proxies where the following year's value has been used: Luxembourg 2002. No data available for Malta prior to 2002, the 2002 value has been used as a proxy for 2000 and 2001.

When looking at the EU 27 countries, table 3 above, it seems clear that a high R&D intensity is not analogous with high GDP growth. That said, as the EU 27 has many member states that are still far from being developed, especially compared to countries such as Sweden, and since it has previously been established that one should perhaps expect these lesser developed countries to be in a form of in catch up phase, i.e. find themselves in a position where they are benefiting from high growth rates irrespective of their R&D expenditures, the same test has been performed for the EU 15. The results from this test are displayed in table 4 below.

Table 4 – EU 15 R&D Intensities of low vs. high growth countries

EU 15 R&D Intensities of low vs. high growth countries		
Average R&D Intensities 2000-2008		
Year	**Low growth group**	**High growth group**
2000	1.777%	1.865%
2001	1.830%	1.932%
2002	1.825%	1.949%
2003	1.820%	1.924%
2004	1.807%	1.891%
2005	1.794%	1.905%
2006	1.842%	1.950%
2007	1.875%	1.944%
2008	1.945%	2.049%
	Mean	**Mean**
	1.835%	1.934%
	Variance	**Variance**
	0.350	1.311
t-value 1.214		

Calculated based on data from Eurostat.

Notes: High growth countries: United Kingdom, Sweden, Finland, Spain, Luxembourg, Greece and Ireland.
Low growth countries: Italy, Portugal, Germany, Denmark, France, Belgium and the Netherlands.
Proxies where the previous year's value has been used: Luxembourg 2001; Greece 2000, 2002, 2008; Sweden 2000, 2002. Proxies where the following year's value has been used: Luxembourg 2002.

In the case of the EU 15, the pattern displayed by the EU 27 in table 3 has been reversed. The EU 15 group instead revels that countries with a higher R&D intensity face higher growth. However it is not a clear-cut case as the R&D intensities do not differ all that much between high and low growth countries in the case of the EU 15, a point echoed by the low level of significance. While the difference between the means in the EU 27 case was statistically significant at the 1% level (two-tailed) the EU 15 case does not even reflect a 10% level of significance. Consequently the answer to the question whether more developed economies that show high growth rates also exhibit high R&D intensities is rather ambiguous, whilst it is clear that when the same analysis takes into account the lesser developed members the evidence is very strong that high growth is *not* analogous with high R&D intensities. This analysis can thus be seen as confirming the existence of a catch-up phase and a convergence within the union as a whole. However it may also be seen as plausible piece of evidence that R&D activity may have different effects on countries' growth based on their level of development, as is reflected by the change in the results from the EU 27 to the EU 15 case. Moreover, even though the results show a low level of significance the EU 15 results may reflect that there has existed somewhat of a divergence amongst the developed economies, in spite of the overall convergence previously emphasized. The variances should also be noted as the variance for the low growth group of the EU 27 is far greater than that of the high growth group, whilst this relationship has been turned on its head in the case of the EU 15. This however need not mean all that much as Sweden and Finland – who have the highest R&D intensities out of the EU 27 – both fall within the low growth group in the EU 27 case and the high growth group in the EU 15 case, and the variances show far less of a discrepancy if these two countries are not taken into account.

4.3.2 The correlation between the growth in real GERD and real GDP

Just as the previous analysis was in place as it was indeed hard to see any real pattern between the real GDP growth rate and the R&D intensity in the descriptive section, this analysis will statistically test the correlation between the changes in real GERD and real GDP as no such pattern could be convincingly established from a visual inspection of the data. However, such a correlation may indeed exist, therefore before testing for a causal relationship between the R&D expenditure and the GDP growth these variables will first be tested for correlation. As a correlation between two variables *may imply* causation but *need not imply* any causality. However, as pointed out by Feinstein and Thomas (2008, p. 72) "[i]t is very easy to get an association between two variables even when there is no plausible hypothesis that might cause one to influence the other. This can occur either coincidentally, because the two variables are independently moving in the same directions, or – more commonly – because the movements in both variables are influenced by some (unspecified) third variable." However, correlation may nonetheless be seen as a necessary precondition for causation and thus the correlation coefficients (r) and their statistical significance need to be calculated. The calculation of the correlation coefficient can be summed up as follows:[16] firstly, the covariance[17] of the two variables Δ GDP and Δ GERD is found through adding up the products of the deviation of each annual value of the mean of each series, which is then divided by the number of cases. To find the correlation coefficient the covariance is then divided by the product of the standard deviation (S) of both series. Once the correlation

[16] The calculations presented here are adapted from Feinstein & Thomas (2008) chapters 3 and 6. For more detailed explanations of correlation coefficients please refer to chapter 3 (pp. 71-114) and for the t-tests chapter 6, sections 6.4.2 through 6.7.3 (pp. 164-175).

[17] The covariance of two variables is, as defined by Feinstein & Thomas (2008), equal to the sum of the products of the deviations from their respective means, divided by the number of cases (p.80).

coefficients have been calculated their statistical significance needs to be reported, which can be facilitated through a t-test with a null hypothesis[18] of zero correlation, i.e. by setting the correlation coefficient of the population (ρ) equal to zero. This will then test the relationship between the actual sample statistics (r) to a hypothetical sample statistic, also known as the t_{calc}, which reflects the deviation of the sample statistic from the statistic defined by the null hypothesis (in this case set to zero). The EU 27 results are reported in table 5 below.

Table 5 – EU 27 t-test for correlation coefficients 2000-2008

t-test for correlation coefficients (H_0: $\rho = 0$)			
Country	r	t_{calc}	Rejection of the null hypothesis
Austria	-0.171	0.425	No
Belgium	0.352	0.921	No
Bulgaria	0.440	1.201	No
Cyprus	-0.824	3.568	**Yes*** **
Czech Republic	0.808	3.363	**Yes*** **
Denmark	-0.500	1.413	No
Estonia	0.358	0.939	No
Finland	-0.155	0.383	No
France	0.298	0.765	No
Germany	0.617	1.922	No
Hungary	0.279	0.712	No
Ireland	-0.206	0.517	No
Italy	0.730	2.616	**Yes** **
Latvia	0.483	1.353	No
Lithuania	0.441	1.205	No
Luxembourg	0.344	0.896	No
Netherlands	0.360	0.945	No
Poland	0.805	3.324	**Yes*** **
Portugal	0.347	0.906	No
Romania	0.415	1.118	No
Slovakia	0.423	1.143	No
Slovenia	0.071	0.173	No
Spain	0.111	0.272	No
United Kingdom	-0.302	0.775	No
	Period	**2000-2008**	
	Observations	**8**	

Calculated based on data from Eurostat.

Notes: Greece, Malta & Sweden have been dropped due to breaks in their series.
*, **, ***, **** refer to rejection of the null hypothesis of no correlation at the 10, 5, 2, and 1 percent levels (two-tailed), equalling the following critical values for 6 degrees of freedom (n-2) in the t-distribution: 1.943, 2.447, 3.143, 3.707.

[18] A null hypothesis, as defined by Feinstein & Thomas (2008), "specifies the negative form of the proposition to be tested" (p. 152), in this case such a hypothesis would consequently be formulated as follows: there is *no correlation* between the changes in GERD and the changes in GDP.

The results in table 5 may seem rather surprising, as correlation is typically quite easy to detect, even when the series are not causal, or even correlated for that matter. However it should be noted that the weak results could stem from several factors: firstly, and the most obvious one, is of course that the series are not correlated; secondly, it could also be the case that that they are correlated but that the time span is not long enough to detect the correlation (this will consequently be tested for by expanding the time frame); and thirdly, a point related to the second, which is that the size of the sample greatly affects the outcome of the test. Consequently, if the sample is very small – such as the one above – then the correlation needs to be very strong in order for (*r*) to be statistically significant. However, by reviewing the few statistically significant results in table 5 we find that indeed only one of these is a high income OECD country, namely Italy, thus not supporting the theory that developed economies have a stronger correlation between R&D expenditures and economic growth. On the other hand Cyprus, who reflects a negative correlation may suggest otherwise; however, all in all the results do not strengthen the case for causality between the R&D expenditure and growth. In fact even if we set the statistical significance aside for a moment no pattern can be found in the correlation coefficients that would suggest that there is a stronger positive link between real GERD and real GDP for more developed countries. Moreover, even though correlation *could* imply causation it says nothing about the direction in which this causation would be going and consequently it could very well be the case that GDP growth increases GERD and not vice versa. In addition one could furthermore imagine that the causation could for instance run in opposite directions for high and low income countries. However, as the majority of the cases reported are deemed to not be statistically significant, i.e. as not being able to reject the null hypothesis of zero correlation at, at least a 5% level of significance, let us move on to testing the correlation for the group of high income EU countries that were used in section 4.2.5. The series have in this case been extended back to 1985, as to see whether a correlation can be detected in the longer run. The results for the "EU 7" (less Denmark who has been dropped due to breaks in the series) as well as Finland are reported in table 6.

Table 6 – EU 7 t-test for correlation coefficients 1985-2008

t-test for correlation coefficients (H_0: ρ = 0)			
Country	*r*	t_{calc}	Rejection of the null hypothesis
Spain	0.453	2.328	**Yes******
France	0.529	2.859	**Yes**********
Italy	0.561	3.106	**Yes**********
Netherlands	0.297	1.427	No
Austria	0.358	1.759	**Yes***
Finland	0.575	3.217	**Yes**********
United Kingdom	0.446	2.284	**Yes******
	Period	**1985-2008**	
	Observations	**23**	

Calculated based on data from Eurostat.

Notes: *, **, ***, **** refer to rejection of the null hypothesis of no correlation at the 10, 5, 2, and 1 percent levels (two-tailed), equalling the following critical values for 21 degrees of freedom (n-2) in the t-distribution: 1.721, 2.080, 2.518, 2.831.

The results displayed in table 6 demonstrate how all countries but the Netherlands have to assume a statistically significant, and positive, correlation in the longer run. A result that thus reflects that there *may* be a causal relationship in the longer run. However, as stated earlier these tests are highly sensitive to the size of the sample when the sample is small, so we should perhaps not read too much into the difference in the results. Moreover it should perhaps also be stressed that since the t-statistic is heavily influenced by the sample size the results of the two tests are not necessarily comparable.

4.3.3 Regression analysis

This section will statistically test the relationship between the variables in table 1 as to see what factors may have contributed to the growth in the 21st century.

4.3.3.1 Previous findings

Most previous studies that have studied the relationship between R&D expenditure and the growth of GDP do so through some type of an *AK* production function. In cross-sectional investigations the production function typically takes the following shape:

$$\log(Q) = \log(A) + \lambda + \alpha\log(K) + \beta\log(L) + \gamma\log(R) + \varepsilon t \qquad (1)$$

or sometimes the shape of equation 2, which takes into account the lagged effect of capital and R&D expenditure upon the output:

$$\log(Qt) = \log(A) + \lambda t + \alpha\log(K_{t-1}) + \beta\log(Lt) + \gamma\log(R_{t-1}) + \varepsilon t \qquad (2)$$

The studies that instead try to find the effect upon the changes of growth through the changes of the other variables over time, i.e. using time series data instead of cross-sectional data typically make use of the following equation:

$$\Delta Q = \lambda + \alpha \Delta Kt + \beta \Delta Lt + \gamma\, \Delta Rt + \Delta \varepsilon t \tag{3}$$

Where typically,

$\Delta Q = (Q_t - Q_{t-1})$

$\Delta K = (K_{t-1} - K_{t-2})$

$\Delta L = (L_t - L_{t-1})$

$\Delta R = (R_{t-1} - R_{t-2}$

$\Delta\varepsilon = (\varepsilon_t - \varepsilon_{t-1})$.

And where α, β and γ denote the elasticises of Q (output) with respect to capital, labour and R&D respectively. However some studies also substitute $L_t - L_{t-1}$ for $L_{t-1} - L_{t-2}$, and $\varepsilon_t - \varepsilon_{t-1}$ for $\varepsilon_{t-1} - \varepsilon_{t-2}$.

The success rate of these estimations nevertheless tends to be low when it comes to finding statistically significant results for the parameter γ, when measured at the aggregate level, especially in the case of time series analyses. Indeed the findings have not become much better since Patel and Soete (1988, p. 162) proclaimed that due to the large variations of the results of measuring the effect of R&D upon growth "[e]conometric studies in this area need therefore to be interpreted and taken with a large measure of scepticism. They provide useful hints and indications of presumed econometric relationships, which are however largely obscured by the difficulties in approximating some of the most crucial concepts." When measured at the industry or firm level[19] significant results are nonetheless often found, especially when cross-sectional data has been used; however, the cross-sectional studies on average find that the effect of R&D activities upon output is higher than when time series are used. Studies that use data at the aggregate level[20] are harder to come by, the reason for this is probably twofold: firstly the data, especially with respect to time-series analyses has been very limited, whilst the second reason must be seen as being the difficulty of finding any statistically significant results when the data has been aggregated as there are so many forces pulling the series in different directions. However, based on the studies at the industry level

[19] See for instance Mansfield 1965, 1980; Griliches 1973, 1988; Griliches & Mariesse 1984, 1990; Hall & Mariesse 1995.

[20] Nadiri 1980; Coe & Helpman 1995; Patel & Soete 1988, are some of the few studies that have used data at the aggregate level.

the elasticity of output with respect to R&D expenditure tends to, as pointed out by Griliches (1988), on average be measured to be somewhere around 0.1 to 0.2. The problem of finding statistically significant results when using time-series data becomes evident in a study of French firms by Hall and Mariesse (1995) who show that the results are only statistically significant while using level data. As soon as they move from cross-sectional data, i.e. level data, to time-series data, i.e. growth data, their analysis becomes statistically insignificant.

Moreover some studies have suggested that causality may only be found in developed countries, countries that are no longer in a catch-up process and who are utilizing R&D to shift out their PPFs. However even in this instance previous studies diverge on the question of causality. Birdsall and Rhee (1993) for instance found, through employing cross-country regressions, that there is a positive correlation between economic growth and R&D investments in developed countries; however, they did not find any support for the claim that R&D had a causal effect on economic growth. On the other hand Fraumeni and Okubo (2005) indeed found such causality when studying American time-series from 1961-2000. In their study they capitalized R&D expenditure in the national accounts, i.e. they treated R&D outlays as investments rather than expenditures, and found that R&D investments accounted for 2 – 7% of the growth rate over that period depending of the deflators used.[21] Consequently, contrary to Birdsall and Rhee, Fraumeni and Obuko found a causational relationship between R&D expenditure and GDP growth, but even so, if R&D expenditures (investments) only have an elasticity of .02 to .07 then that would be the same as saying that if the growth rate increases by 1% only 0.02% to 0.07% of this increase can be contributed to the R&D activities. Reflecting that even in the presence of statistically significant results, GERD has an almost negligible effect on the growth rate, at least as compared with the generally assumed output elasticity with respect to traditional capital, which tends to hover around 0.3. It is moreover not certain that these findings would be applicable to the EU countries.

4.3.3.2 The contribution of R&D expenditure to GDP growth in the 21st century

If we knew what we were doing it wouldn't be research. – Albert Einstein

As shown in the previous section the problem of measuring the effect of R&D upon growth is common throughout the literature, indeed few studies find statistically significant result through the use the *AK* production function, and those that do show high variations in their

[21] Please see "Appendix A," pp. 301-307 in Fraumeni and Okubo (2005) for full details.

results. Due to the low success rate of these models at the aggregate level I have decided to take an unusual route to instead try and gauge the effect of GERD upon by GDP during the 2000-2008 period through the following equation:

$$\log(Q_{2008} - Q_{2000}) = \lambda + \alpha\log(R_{2008} - R_{2000}) + \beta\log(P_{2000}) + \gamma\log(Qcap_{2000}) + \sigma \log(Int_{2000}) \quad (4)$$

Where Q denotes output or GDP; R the R&D expenditure; P the size of the population; Qcap the GDP per capita; and Int the R&D intensity. This procedure has been done as to see if one can indeed see an effect of the growth in GERD upon the growth in GDP while accounting factors that have been suggested by the literature as being of great importance for the effect of R&D activity upon economic growth. The initial R&D level would consequently fill two functions, in the first instance it reflects whether countries that have a higher level of initial R&D indeed receive a higher output thanks to these activities as the R&D is used to shift out the PPF, i.e. the initial income ought to have a positive relationship with growth in economies that are close to the technology frontier. However, the initial R&D level may have another effect as well as it to a certain extent reflects the absorptive capacity of spillovers, as one can perhaps assume that a country needs to have some form of an R&D knowledge base in order to appropriate the knowledge from spillovers. The latter point also ties in with the initial size factor as it has been suggested that larger economies may be at an advantage to grow as they face greater possibilities to absorb internal spillovers; an argument that largely rests upon an assumption that national boarders somehow constrain spillovers to remain within the country, in effect granting large economies an advantage over the smaller ones. Finally this then brings us to the variable that may be of the greatest interest for the discussion of the effect of GERD upon GDP, namely the GDP per capita. The GPD per capita has been chosen as a measurement of the level of development of the countries as the level of development is the most reoccurring factor that is assumed to have an effect on the GERD / GDP relationship. The income level is assumed to play a role as relatively poorer countries may be in a position of catch-up and consequently one may find reason to believe that there should be a negative correlation between the initial income level and the rate of growth for less developed countries, but that this relationship ought to be positive for the highly developed ones, for whom R&D may be used to “create” growth where it would otherwise be hard to grow. Also the level absorption of spillovers ought to be positively related to the level development as high levels of development are often analogous to high levels of education. In effect then this model tries to measure how much of the 2000-2008 growth can be attributed to the above mentioned factors. The results for the EU 27 can be found it table 7 below.

Table 7 – Cross-country regression results EU 27

Regression Results EU 27*		
Method: Cross-Country OLS		
Dependent Variable: Percentage change in real GDP (log diff 2000-2008)		
Independent Variables	**Coefficient**	**P-value**
Constant	2.7672	0.0000
Percentage chage in real GERD (log diff 2000-2008)	0.0354	0.5079
Initial R&D Intensity (2000)	2.1848	0.6474
Initial real income (2000)	-0.1659	0.0002
Initial size (2000)	-0.0580	0.0070
Observations	24	
Adjusted R-squared	0.7275	
Prob (F-statistic)	0.0000	
R&D intensity dropped		
Independent Variables	**Coefficient**	**P-value**
Constant	2.6884	0.0000
Percentage chage in GERD (log diff 2000-2008)	0.0282	0.5722
Initial real income (2000)	-0.1554	0.0000
Initial size (2000)	-0.0571	0.0063
Observations	24	
Adjusted R-squared	0.7382	
Prob (F-statistic)	0.0000	
Size dropped		
Independent Variables	**Coefficient**	**P-value**
Constant	1.5772	0.0003
Percentage chage in GERD (log diff 2000-2008)	0.1056	0.0726
Initial R&D Intensity (2000)	0.7772	0.8900
Initial real income (2000)	-0.1410	0.0028
Observations	24	
Adjusted R-squared	0.6168	
Prob (F-statistic)	0.0001	
R&D intensity & size dropped		
Independent Variables	**Coefficient**	**P-value**
Constant	1.5553	0.0001
Percentage chage in GERD (log diff 2000-2008)	0.1027	0.0542
Initial real income (2000)	-0.1373	0.0003
Observations	24	
Adjusted R-squared	0.6347	
Prob (F-statistic)	0.0000	

Estimated based on data from Eurostat.

Notes: EU 27* = EU 24 as Greece, Malta and Sweden have been dropped due to breaks in the series.

The initial regression results exhibit a high adjusted R^2, which reflects how well the regression line can be fitted onto the "true" regression line, i.e. it reflects how much of the variations of the dependent variable can be explained by the independent variables all together. Moreover, as can be expected with such a high R^2 the F-statistic is low, and as this is a measure of the probability of the R^2 the results having a high explanatory power of the growth in GDP over this period this is a good sign.[22] Additionally it can also be understood that the effects of the initial R&D intensity as well as GERD are not statistically significant, as reflected by their high p-values, which perhaps ought to have been expected based on the low statistical significance of the correlation between the growth in GERD and the growth in GDP, that said I would have thought that they would have been closer to reaching a critical level of significance. On the other hand both the initial *real* income levels as well as the initial size of the economy are highly significant, i.e. display very low p-values. However both these variables have negative effects on growth as can be understood from the sign of the coefficients. The fact that high income has a negative effect on the rate of economic growth could consequently be seen as a form of confirmation of an ongoing catch-up and convergence in the EU 27, which is indeed what the literature predicts. However, the expected effect of the initial size runs in the opposite direction, which reveals that instead of the large countries benefiting from growth through spillovers it has instead been the smaller countries that have grown relatively more. This would consequently, contrary to what the endogenous growth literature predicts, reflect that smaller economies may be at an advantage, perhaps especially with the existence of a catch-up process as it could indeed be easier for small economies to quickly adopt new technologies as well as adapt to other economic conditions.

Even though the overall explanation power of the model is very high we can try to increase the explanation power of the independent variables by dropping variables that may be seen as not having a positive effect on the result. This procedure is especially important if we suspect that there may be collinearity, if not multicollinearity, among the independent variables i.e. that two or more of the independent variables are highly correlated to each other, as this could – but does not necessarily have to – have an effect on the prediction power of the model as a whole but would certainly reduce the prediction power of the individual variables. On the other hand, it could nonetheless be argued that there is always a

[22] It may seem counterintuitive that a low probability is good; however, it should more so be thought of as a measure of the probability of being able to reject a null hypothesis that the independent variables did not account for a certain amount (equal to R^2) of the variation of the dependent variable.

chance that collinearity exists, and perhaps we have to, as suggested by Feinstein & Thomas (2008 p. 323) acknowledge that "multicollinearity has to be accepted as an occupational hazard of running regressions." When dropping the initial R&D intensity, the variable that had the lowest level significance and which might also have been skewing the effects of the change in GERD upon the change in GDP – as the R&D intensity is indeed the ratio of GDP and GERD (albeit in nominal terms) and could thus reflect a high degree of collinearity. As can be seen by the slight increase in the adjusted R^2 and the slight probability increases of the initial income and size levels this renders the model negligibly better at explaining the growth in GDP over the period, however overall the results stay more or less unchanged. Next, the size of the economy was dropped, which had a huge effect upon the explanation power of the change of GERD to the extent that it almost became statistically significant, while slightly affecting both the significance of the real income level as well as the adjusted R^2; however, these effects were unfortunately not enough to largely alter the overall results. That said, when dropping both size and intensity levels the change in GERD becomes statistically significant if we lower the standard significance level from the normal 5% to 10%, and it is shown to have a positive effect on growth. However, by looking at the size of the coefficient it can be understood that, even if we would deem this statistically significant, a one percent increase in GERD would roughly only result in a 0.1% increase in the growth of GDP; a result far from a strong causality of R&D expenditure upon growth and definitely far from the proportional relationship suggested by some of the endogenous growth theories. All in all the "goodness of fit" of the model, i.e. the R^2, stays high throughout the analysis, and so does its probability (low F-statistic), that said the adjusted R^2 was positively affected by the dropping of the R&D intensity whilst negatively affected by the removal of the size factor. Moreover, the negative effect of the initial income level upon growth seems to be in line with the literature; however the negative effect of size is the opposite effect of what the literature had predicted.

Turning then to the case of the EU 15, which is represented by the EU 15 less Greece and Sweden, reported in table 8, the exact same adjustments (drops) have been made as in the EU 27 case. Consequently facilitating a comparison not only the results of the initial estimation of the model, but also what differences the same changes made in the two cases.

Table 8 – Cross-country regression results EU 15

Regression Results EU 15*		
Method: Cross-Country OLS		
Dependent Variable: Percentage change in real GDP (log diff 2000-2008)		
Independent Variables	**Coefficient**	**P-value**
Constant	-2.8024	0.2178
Percentage chage in GERD (log diff 2000-2008)	0.2299	0.1425
Initial R&D Intensity (2000)	-0.3404	0.9400
Initial real income (2000)	0.2769	0.1203
Initial size (2000)	0.0064	0.8428
Observations	13	
Adjusted R-squared	0.2829	
Prob (F-statistic)	0.1613	
R&D intensity dropped		
Independent Variables	Coefficient	P-value
Constant	-2.8088	0.1886
Percentage chage in GERD (log diff 2000-2008)	0.2337	0.0948
Initial real income (2000)	0.2764	0.0987
Initial size (2000)	0.0066	0.8266
Observations	13	
Adjusted R-squared	0.3621	
Prob (F-statistic)	0.0730	
Size dropped		
Independent Variables	Coefficient	P-value
Constant	-2.4188	0.0236
Percentage chage in GERD (log diff 2000-2008)	0.2088	0.0483
Initial R&D Intensity (2000)	-0.4212	0.9209
Initial real income (2000)	0.2503	0.0185
Observations	13	
Adjusted R-squared	0.3592	
Prob (F-statistic)	0.0744	
R&D intensity & size dropped		
Independent Variables	Coefficient	P-value
Constant	-2.4104	0.0167
Percentage chage in GERD (log diff 2000-2008)	0.2126	0.0229
Initial real income (2000)	0.2486	0.0120
Observations	13	
Adjusted R-squared	0.4226	
Prob (F-statistic)	0.0258	

Estimated based on data from Eurostat.

Notes: EU 15* = EU 13 as Greece and Sweden have been dropped due to breaks in the series.

Looking at the results from EU 15 we can deduce that the model explains the economic growth relatively poorly as compared to the EU 27 case. The adjusted R^2 is however by no means extremely low, and rather counter-intuitively it increases as the variables are dropped. Moreover the F-statistic shows that the model is not statistically significant at the 5% level of significance unless both the R&D intensity and the size are dropped. In this instance both the change in GERD and the initial income level, which both have positive effects on the growth, are statistically significant at the 5% level. Additionally, as compared to the results from the EU 27, the explanation power of the growth of GERD upon the growth in GDP has doubled, a finding which would then be in line with the reasoning that more developed countries – those who are close to or at their PPF – benefit more from R&D expenditure. The case of the latter hypothesis is further strengthened by the fact that the EU 15 also displays a positive effect of the initial income level, whilst the opposite relationship was found in the EU 27. However the effect of the initial high income would also support the instance of a divergence within the EU 15, as the richer are growing richer, a point already alluded to in section 4.3.1.

Overall we can conclude that the initial income level had an effect upon growth; however, the effect was positive the case of the EU 15 whilst negative in the EU 27 case. The EU 15 results were nonetheless only statistically significant after both the initial size and the initial R&D intensity had been dropped. Furthermore, the initial R&D intensity had very low explanation powers in both groups; however, this could partially have been due to collinearity with the growth in GERD variable. The initial size of the economy was statistically insignificant in the case of the EU 15, which perhaps could be seen as hint toward size not actually mattering all that much for the more developed economies; in the EU 27 case the effect of the size factor nonetheless had a negative effect upon growth, a result that breaks with the expected effect based on endogenous growth theory. Moreover the statistical significance of the change in GERD was low in both cases apart from in an extremely reduced model, which should perhaps have been expected as the correlation between the change in GERD and the change in GDP was largely statistically insignificant for the same period in the previous analysis in section 4.3.2. The low level of significance of the effect of GRED furthermore largely echoes the results obtained in previous studies of its effect upon GDP at the aggregate level.

The regression results consequently reveal little evidence that can support the assumed causality between real GERD and real GDP in the short run, i.e. the 21st century. However, the R^2 and the F-statistic are nonetheless perhaps of the highest importance as they reflect how well the regression line fits the "true line" or how much of the variation of the dependent variable can be explained by the variations of independent variables, and the overall statistical probability of the explanatory capacity of the regression as measured by R^2, respectively. However it should be kept in mind that the R^2, or the adjusted R^2 as reported here – which takes into account the number of independent variables in the estimation – does nonetheless not reflect whether these changes in the dependent variable were in all actuality caused by the independent variables chosen, it just shows the probability of them being able to explain the changes to a certain extent, as indicated by the size and significance level of R^2. Consequently one should more so regard the results as their probability in measuring the effects upon growth, and not take for granted that these variables were indeed what caused these changes as there in all actuality does not exist any guarantees that a high R^2 and low F-statistics indeed reflect that the variables chosen were what caused the changes in GDP in reality.

4.4 Conclusions that can be drawn from the empirical findings

In conclusion then, the actual data and the empirical analyses in chapter 4 have shown that there seems to be no uniform pattern in the real growth rates of countries based neither on their real R&D expenditure, nor their R&D intensities. Furthermore one should be a bit weary of the R&D intensity and GDP relationship, especially in the short run as the GDP, albeit in nominal terms, is indeed the denominator in the calculation of the R&D intensity. As such, the R&D intensity could be a bit of a misleading measure of the actual R&D expenditure as a large increase in the actual R&D expenditure could be precluded in the intensity measure if coupled by a large increase in GDP, the reverse relationship would likewise also be true where the intensity could increase if there were to be a drop in GDP without being coupled by a drop in the R&D expenditure. However, these occurrences ought perhaps to be seen as short term effects before the GERD has "caught up" to the changes in growth, or vice versa. Furthermore it has been shown that in the case of the EU 27 high growth seems to be analogous with low R&D intensities, which could imply that there is an ongoing catch-up process in the EU 27. The opposite relationship can also be observed for the EU 15, where "high growth" countries on average exhibit higher R&D intensities than "low growth" countries, however the evidence of this is nonetheless rather weak as the difference between the means of the high and low growth groups is not statistically significant in the EU 15 case. This could nevertheless be taken as a small piece of evidence that R&D might be seen as an outlet for growth once a country has reached a certain level of development, but that R&D matters comparably less for the growth of lesser developed economies, which would largely be in line with the reviewed literature. Moreover, the correlation between the changes in R&D expenditure and growth in the EU countries ranges from high and negative to high and positive in the short run, however on average the results are statistically insignificant which lends little support to a causality in the short run, albeit not refuting the existence of such a relationship. In the longer run, a strong positive correlation does seems to exist between the changes in GERD and the changes in GDP, at least for the developed high income countries in the EU. That said, even though a strong and statistically significant correlation has been found in the long run, there is nothing that suggests that this would have to be a causal correlation, and even if it were, this causality could indeed run in the opposite direction where high levels of GDP growth lead to high levels of GERD growth and not vice versa.

The regression results are largely in line with previous studies at the aggregate level. The effect of R&D expenditure upon GDP was largely statistically insignificant, and when significant its elasticity with respect to the changes in GDP roughly ranged between 0.1 to 0.2, which is also in line with previous results. The initial R&D intensity was insignificant in both the EU 15 and EU 27, however this could have had to do with collinearity with GERD. The initial income level proved to have the expected effects that the literature had indicated, where initial income has a positive effect on growth for high income countries, but a negative effect for low income countries. The effects of the size however marked a break with endogenous growth literature as size had a negative effect upon growth in the EU 27 case and was statistically insignificant in the case of the EU 15. Moreover, it seems as though there may have been two separate forced at play in the EU 15 and the EU 27, where there has been a divergence in former and a convergence in the latter. The results are far from perfect; however, I find no reason to support the assumed strong causal relationship between GERD and GDP, at least not in the short run. It should nonetheless be mentioned that even though I find no support for such causality I cannot completely confidently reject it either. It does nevertheless seem clear that the structural effects during the investigated period clearly outweighed the effects of the R&D expenditure in both of the groups studied. On the other hand, even though many studies – including this one – fail to show a statistically significant causal link between R&D expenditure and GDP growth one could of course argue that there at least exists *casual evidence* of such a link. After all, if R&D did nothing to increase productivity (and consequently growth if the other inputs were not to be drastically decreased) then why on earth would companies be willing to invest in R&D in the first place? This of course need not be true at the government level where the same assumptions of trying to maximize profits need not exist.

5 Policy implications

Politics is the art of looking for trouble, finding it everywhere, diagnosing it incorrectly and applying the wrong remedies. – Groucho Marx

In contrast with the preceding chapter – which I deem to be largely based on positive findings – this chapter will be rooted in what *I believe* the correct policy implications of such a paradox *ought to be* and will consequently be of a more normative nature. This section will attempt to evaluate the validity of choosing a 3% R&D intensity for all EU members and of increasing R&D expenditure incentives through a form of government subsidisation. These discussions would have been far more polemic if I had found probable cause to believe that such a phenomenon as a Swedish R&D Paradox indeed existed – as implementing such policies seems utterly ironic, if not absurd, if Sweden were to be deemed a paradox. However, even though such a paradox may not exist, neither has a strong causality between R&D expenditure and GDP growth been established, and even if we assume that such a relationship would exists it ought to be clear that R&D activity has different effects upon different economies, and consequently there are still quite a few questions that perhaps ought to be raised. There nonetheless exists the distinct possibility that this chapter will ask more questions than it will be able to answer. Not only because the answers may be hard to come by, but perhaps more due to the normative nature of this chapter. Indeed if the analysis was black and white in the descriptive section, and the explanatory section added a few shades of gray to the palette, then this section adds colours from the entire colour spectrum, making it somewhat of a slippery slope.

5.1 The Lisbon Strategy's 3% R&D intensity aim

The 3% target drawn up in Lisbon in 2000 and ratified in Barcelona in 2002 seems to be sound reasoning if there were indeed a clear *causal* relationship between R&D expenditure and economic growth. However since innovation indeed is contingent upon other factors there is no guarantee that R&D leads to innovations in the first place, and most certainly not innovations that have an impact on the growth in the second. The statistical analyses in chapter 4 may have largely failed to show statistically significant result; however, it does seem rather clear that if such a thing as a Swedish paradox has existed in the past it has faded away in much the same fashion as the American productivity paradox of the 1970s and 80s did in the 90s. As could be seen in figure 2 Sweden has during the 21st century not only had an average growth rate considerably above the EU 15 average but also above both the US and the EU 27, irrespective of potential catch-up processes in some of the EU 27 countries.

However, it is also indeed likely that the expected effect of R&D expenditure upon the growth rate has been hyped up to unreasonable levels. Moreover, even when such causality can be inferred from the statistical analyses the relationship between the changes in GERD are far from proportional to the changes in GDP. Additionally, as this study has shown the correlation between the changes in GDP and GERD may become weaker and weaker the shorter the time frame becomes. Furthermore, as it has been shown that the R&D intensity, at least in the short run, need not reflect the increases of the actual R&D expenditure all that well (as high GDP growth may very well preclude even substantial increases in GERD in the intensity measure) the R&D intensity measure may be a rather poor reflection of a country's innovativeness. Consequently I believe that it is indeed valid to question the soundness of choosing a 3% R&D intensity target for all EU member states.

There are many questions that perhaps ought to be raised, but this study will limit itself to discussing a few of these. Firstly, if we assume that it is indeed easier to grow when in a catch-up position, and if the European Commission is in fact striving for what they refer to as "cohesion"[23] within the union, then what is the rationale for setting up a 3% target? Furthermore, if the goal is to create a truly unified entity, where countries although remaining individual countries are more or less part of a large National System of Innovation (NSI) then what is the purpose of trying to create clusters in largely agrarian and rural countries?[24] Would it not perhaps be better to let the already existing clusters grow and instead revert back to internal trade along the lines of comparative advantage? That way the agricultural subsidies can be diminished whilst allowing the lesser developed member states to grow on their own terms. Also, as pointed out by Ola Jonsson, creating industrial nodes within these countries may result in negative results such as mass migration from the rural to the urban areas, which would in effect create a form of brain drain in the rural areas whilst perhaps putting a toll on the welfare system in the urban areas as even unskilled labour would migrate and perhaps not find suitable jobs as they lack the necessary skills to acquire these jobs.[25] Furthermore, it has to perhaps be assumed that head on competition between developed and less developed members will neither serve the catch-up countries nor the union as a whole much good as it would arguably be relatively more expensive for the lesser developed

[23] The European commission has stated that it strives to create cohesion in the union through an "innovation and knowledge-based economy [by] strengthening regional capacities for research and technological development, fostering innovation and entrepreneurship and strengthening financial engineering notably for companies involved in knowledge-based economy" (ec.europa.eu). Last accessed on 15/12/2009.

[24] According to the EU Commission's own web page (ec.europa.eu) "more than 91 % of the territory of the EU is 'rural', and this area is home to more than 56 % of the EU's population." Last accessed on 15/12/2009.

[25] Lecture at Lund University Dec. 14 2009.

countries to try and develop the same type of technologies as the technological leaders are already developing. Secondly, if we assume that R&D has different effects upon growth in different countries due to for instance their level of development or education, then why is there a universal target and not individually tailored targets? If indeed some countries can be assumed to greatly benefit from R&D activity, i.e. those close to the technological frontier, then why s not more than a 3% intensity asked of them, and why is a 3% target asked of those who may indeed benefit far more from simply adopting technologies rather than developing them? As a long term goal, it *may* be advisable to have a high R&D intensity; however, what is the point of setting up such a target if countries cannot benefit from it in the short run? Of course I see the point in having long term goals, yet the first goal ought to be to increase the living standards in the poorer member states *here and now*, and this should arguably be easier to facilitate through adoption and adaption of R&D knowledge and technologies developed elsewhere where they are relatively cheaper to produce.

Moreover a 3% target says little about what type of R&D that is to be performed. If there are considerably different returns to private and publicly performed and funded R&D then the outcomes can be drastically different for countries that choose to depart upon different R&D paths. Indeed I believe that setting up a universal target, especially without making clear stipulations as to how the 3% R&D intensity should be reached may be analogous with setting ourselves up for disappointment. Not only may the assumed large effect upon the growth rates shine with its absence, but it may also lead to problems of increased reliance on internal subsidisation and redistribution, not to mention the potential mass migration. I for one do not see the “problem” in the supposed “freeriding problem” I only see the “freeriding” and I have found little evidence of this being a problem for the economic growth of the union.

5.2 Increasing Swedish R&D investment incentives

VINNOVA, *the* Swedish Governmental Agency for Innovation Systems is on a mission to “*promote sustainable growth* by funding *needsdriven* [sic.] *research* and developing *effective innovation systems*.”[26] As such it is one of the main actors in trying to develop the competitiveness of Sweden and Swedish firms in the international arena. According to VINNOVA (2008) many countries have increased the incentives to invest in R&D via tax reductions, and since Sweden lacks such an incentives system, VINNOVA has suggested that

[26] Asserted by Göran Marklund – Associate Professor of Innovation and Economic Change at Uppsala University and Head of the Strategy Development Division at VINNOVA – in the foreword to Svensson (2008).

Sweden ought to implement such a policy. Consequently, this section will explore the validity of implementing such a policy in one of the world leaders of R&D expenditure as compared to GDP, i.e. R&D intensity. As such there are three possible scenarios that may be of importance to discuss, namely:

- If Sweden were to be a paradox - which would in my opinion, at least at first glance, render such a policy as outright folly.
- If it is however indeed the case that the relatively speaking high growth experienced in Sweden and Finland during the beginning of the 21st century is in fact the resolution of a previous paradox where the returns to the prior high levels of R&D spending finally started to pay off, then it should perhaps be clear that increasing the R&D spending ought to be a reasonable way to go about creating sustainable growth. However, choosing such a path may then mean that we have to tighten our belts in the short run in order to facilitate growth in the longer run.
- If Sweden is no more of a paradox than other countries, but if we have previously expected too large of an effect of R&D activities upon growth than this instead becomes a question of whether the pros will outweigh the cons of implementing such an incentive structure – as it should be clear these “incentives” need to be financed somehow. The question then becomes whether or not reducing funding for other social spheres would cost the overall economy more than we could plausibly expect to gain from the increased R&D spending?

Based on the actual data presented in chapter 4 I believe that one should be weary of talking about a Swedish R&D Paradox, at least in the 21st century as Sweden has compared to most other developed economies performed well in terms of GDP growth, but perhaps even more so as the explorative section as well as previous studies have not found a very strong causal relationship between the variables in general. As such, I find little reason to discuss the first point much further. However, if there would have been grounds for discussing such a thing as a R&D paradox in Sweden and that such a phenomenon for instance stemmed from low commercialization of the research performed, as suggested by Ejermo and Kander (2004), then perhaps the most logical way to increase the effect upon GDP from these undertakings would be to start manufacturing these goods within the country. However such a transition ought to come at the expense of the internal social structure, which hinges upon low skill premiums. Indeed in order to make domestic production more attractive, or even a viable alternative, manufacturing costs must become relatively cheaper, and this will not happen as long as egalitarianism is valued higher than GDP growth. In essence then if the Paradox where to exist, which I do not believe it does, it would perhaps be necessary to make a trade-off between the low skill premium (or an egalitarian social structure if one prefers) and economic growth. Moreover, even though it may be hard to see a basis for the paradox in the aggregate it is nevertheless true that the Swedish high-tech industry is rather concentrated to a few firms. With this in mind, increasing the incentives to invest in R&D through tax cuts may perhaps only create further polarization as it would arguably be the already established firms who would benefit from this as they already have profits from previous periods to invest – a point driven home by Roger Svensson (2008, p. 49) who concludes that "[a]n advantage of tax incentives is that competition between *established companies* is not distorted. New companies with high investment costs and limited sales, i.e. those who are in most need of funding, are at a disadvantage, however." This would consequently serve to undermine the conclusion drawn by VINNOVA (2008, p. 15) that such a policy would create both a widened and deepened R&D base.

However as it has previously been concluded that there may not exist any real reason for talking about a Swedish paradox, at least not in the 21st century points 2 and 3 are of greater in my opinion of greater interest. The evidence put forth by this study, and most certainly by previous studies suggest that the elasticity of output with respect to R&D is, even when statistically significant, very low. Consequently increasing the spending on R&D may have little effect on growth in the long run, and most certainly in the short run. However if it is indeed the case that we are finally reaping the benefits of previous R&D efforts then it may very well be worth the while to increase the spending; however, my main question then becomes: even if we can assume that economic growth is positively affected by the R&D expenditure, where is this money going to come from? Arguably some other sector of the economy will have to pay for this "R&D feast", which then once again reverts back to the question of social structure. Sweden has long prided itself with displaying one of the most egalitarian social structures in the world; however, if an increased spending on R&D would come at the cost of for instance general health care or public schooling, the is it really worth it? In such a case it may be worth sacrificing the growth for the sake of the social structure. Moreover, I find it a very interesting question what shape these "incentives" would take as all expenditures at the firm level are already 100% tax deductible in Sweden, which would mean that these so called incentives would have to come in the form of straight up government grants, and one may very well wonder what the reasoning behind subsidising a profit maximising industry would be? On the other hand I can most certainly see the rationale of increasing the incentives if it can be assumed that firms, unless basically subsidised by the public sector, invest in R&D at a level that can be seen as less than socially optimal. This would thus be in areas where the social return to R&D expenditure is far higher than the private, i.e. where there are large positive spillover effects, and where government subsidisation may indeed be desired if not necessary as firms may otherwise be reluctant to invest in these types of projects. On the other hand, if there is no tight control as to *where* and *how* the firms would spend the money there would be no guarantee that these funds would be spent in a fashion that would indeed have a positive effect on society at large. In conclusion then, increasing the incentives through tax reductions – or more plainly through increased government grants – should perhaps take place even in a country that is one of the world leaders in R&D expenditure as compared to GDP, if the money is indeed funnelled into areas where firms may otherwise not invest; however if doing so it should be kept in mind that this *may* come at the cost of the traditionally egalitarian Swedish social structure.

6 Conclusion

The paradoxes of today are the prejudices of tomorrow, since the most benighted and the most deplorable prejudices have had their moment of novelty when fashion lent them its fragile grace. – Marcel Proust.

According to the data that has been presented in this study I would suggest that it is perhaps most fitting to once and for all lay the Swedish R&D Paradox to rest. Sweden has in terms of growth outperformed most of the other European high income OECD countries, as well as the US and Japan in the 21st century and consequently the paradox is on very thin ice even though Sweden's R&D intensity is very high in relation to other countries. Moreover it should once again be pointed out that the R&D intensity may be a poor reflection of the actual R&D efforts of a country in the short run, as such it is perhaps better thought as a long term reflection of a country's potential for innovativeness – and policy makers ought to not be all too fixated on the R&D intensity when drawing up policies that aim to increase growth. When it comes to the assumed causality between R&D expenditure and GDP growth this study has not been able to establish such a relationship in the short run; however this need not mean that such a relationship may not exists in the longer run. The strong positive correlation found between the changes in GERD and the changes in GDP for the high income countries in the longer run may indeed reflect such causality; however, it is also possible that even if such causality exists that it would be running in the opposite direction where increases in GDP cause the increases in GERD and not vice versa. Consequently perhaps more efforts ought to be devoted to measuring such causality using time-series data, while taking into account very long lags. The importance of applying long lags, becomes apparent if there has indeed existed such a thing as a Swedish Paradox in the past, and that this paradox has finally been unravelled in the 21st century as this may be ground enough to suggest that the lags are far longer than the assumed lags of a few months up to five years advocated by for instance Carson, Grimm and Moyland (1994). In fact this hypothesis would then suggest that it may take an entire generation before the effects of R&D activities can be seen on the growth rate.

The bottom line is perhaps this: GDP growth is made up by many variables, and assuming that R&D has a large effect upon the growth rate may have been grossly overestimated. In fact, I believe that even though R&D *may* have an effect upon the growth rate we should not expect to see tremendous changes in the nearest decades due to the R&D intensity target set up by the European Union. If we set up such expectations I fear that we will only lead ourselves head-on into a growth disappointment of gargantuan magnitude. Indeed Peter Howitt (2004, p. 13), one of the founding fathers of the endogenous growth model with R&D as a factor of production, made this point very clear a few years ago when asserting that "[o]ne of the few unambiguous lessons we have learned from research into the determinants of long-run prosperity is that there is no single magic bullet, no unicausal explanation that leads to a simple recipe for success[,]" a statement that indeed captures the essence of the results from this study. There are many stones that have been left unturned, most certainly in this study, but also on the topic of the actual effect of R&D expenditure upon growth in general – especially when measured in the aggregate. R&D may hold the key to long-term growth; however, more research in this field is needed to truly unveil this relationship. Moreover, just as the endogenous growth theories have flooded the growth literature over the past few decades, so may also another type of model come to dominate the literature in the future. Exciting times may indeed lie ahead of us as the relationship between R&D activities and growth becomes clearer; however, as for now the effect of R&D upon growth is still largely a measure of our ignorance.

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Appendix – R&D exclusions in the Frascati Manual

R&D, according to the Frascati Manual, is defined as "creative work undertaken in a systematic fashion designed to increase the stock of knowledge …" however there are quite a few exclusions from the R&D measure, as such these exclusions as well as the exceptions to the exclusions are presented in table A1 below. Furthermore it should be emphasized that the information in table A1 has been copied *verbatim* from Annex 2 of "A Comparison of International R&D Performance: An Analysis of Countries That Have Significantly Increased Their GERD/GDP Ratios During the Period 1989-1999" written by Charlene Lonmo and Frances Anderson on the behalf of Statistics Canada.

Table A1 – R&D exclusions and exceptions to exclusions in the Frascati Manual

Excluded activity	**Exceptions (included in R&D)**
1. education and training	Independent PhD. and post-doctoral research
2. "other related scientific and technological activities" such as routine data collection, testing and calibration, specialized medical care, legal patent work, routine software development	If done solely for the purpose of R&D support "advanced medical care" involving research carried out in university hospitals software which involves scientific or technological advances
3. "other industrial activities" which includes all other steps necessary for the development and marketing of a manufactured product and the commercial use of a process and equipment industrial production, pre-production and distribution of goods and services	prototype development pilot plants
4. Administration and other supporting activities such as: purely financial activities related to R&D; raising, managing and distributing funds indirect supporting activities such as: clerical support, transportation, cleaning, repair, maintenance and security activities	costs of such activities (part of overhead expenditures by R&D performers)