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The Swedish Paradox arises in Fast-Growing Sectors

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The aim of this paper is to examine whether the previously observed gap between growth of R&D and economic performance, known as the ‘Swedish paradox’, is a general phenomenon across all sectors of the economy, or only occurs in specific industry segments. The dataset used for the analysis covers nearly the entire Swedish economy 1985-1998, divided into five broad sectors: Fast-growing industries, Slow-growing industries, Industrial outphasers, Fast- growing producer services and Other services. The growth of R&D, value added and research productivity is compared for these sectors and the largest gap between R&D and value added is located to the fast growing sectors of the economy. The Swedish paradox is therefore not necessarily a sign of weakness or deficiency of the innovation system, but rather indicates that long-term growth requires large investments in knowledge-building resources.

Keywords: Swedish paradox, sectors, R&D, research productivity, economic growth.

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Olof Ejermo[*], Astrid Kander[#] and Martin Svensson Henning[o]

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Key words: Swedish paradox, sectors, R&D, research productivity, economic growth.

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1. Introduction

The Swedish paradox refers to unexpectedly low innovative output from R&D at the national level of the innovation system (Edquist and McKelvey, 1998). A generalised version of the paradox suggests that both innovative output and economic growth are low (Andersson et al., 2002, OECD, 2005). Graphically illustrated, the generalized paradox shows as a growing gap between R&D expenditures and GDP over time, with R&D growing much faster than GDP. The paradox seems striking in the Swedish case. Sweden is one of the countries with the highest R&D expenditures (around 4% of GDP), but has only experienced average OECD growth since 1950. Indeed, between 1973 and 1993 the growth rate was substantially below average, but since 1994 growth rates have been higher than in the OECD area (Ejermo and Kander, 2008).

A paradox that has also been identified and debated on the European level (Dosi et al., 2006, Acs et al., 2005), refers to seemingly lacking efficiency in public and, in particular, academic R&D.[1] Explanations for the paradox have been sought in weaknesses of the innovation system, such as weak linkages of R&D, inventions, innovations and growth (Acs et al., 2005). Jones (1995) pointed out that the number of scientists engaged in R&D in the US has grown dramatically over the last 40 years, while economic growth rates have not.

Kander et al. (2007) argue that the paradox ought to be solved by toning down expectations. With the co-existence of a Swedish, a European and an American paradox, it is reasonable to believe that economic growth expectations from R&D have been too high. These unrealistic expectations have relied on early and very optimistic formulations of the endogenous growth theory, where economic growth was proportional to R&D investments, because returns to capital in a wide sense (human and physical) did not need to face diminishing returns to scale, but could even have increasing returns (Romer, 1990,

[1] This paper deals with business R&D. There has also been a debate about lack of efficiency in Swedish academic R&D on different accounts. We refer the reader to discussions of Goldfarb and Henrekson (2003), Jacobsson and Rickne (2004) Jacobsson (2002) Andersson and Henrekson (2003). Lissoni et al. (2008) present data showing that patenting levels among Swedish academic researchers do not differ from that of US academics, despite large institutional differences.

Aghion and Howitt, 1992, Grossman and Helpman, 1994). Thus, knowledge spillovers have been perceived as large and R&D as a growth stimulus for the entire economy. In response to the Jones' critique (Jones, 1995), some endogenous growth modelers have adjusted the growth effects from R&D downwards. For instance, Aghion and Howitt (1998, 404 pp) modify their original model so that rising R&D in a steady state does not cause an increase in the growth rate. With this modification, the overly 'optimistic' growth theory probably came to an end. Jones (2002) is even closer to old growth theory, with its emphasis on decreasing returns to investments, when he argues that the present economic growth rates are upheld because of increasing R&D investment ratios. Eventually, economies will no longer be able to increase R&D to GDP ratios further, but will end up with lower growth rates than the ones we see today. Although we subscribe to the view of the great importance of R&D investments in general, we will argue that one key to readjusting the expectations and sharpening the understanding of the interplay between R&D and economic growth further is to specify where a gap between R&D and value added occurs.

Closely related to the discussion about the gap between growth rates for R&D and GDP is the finding that research productivity, defined as the ratio of patents to R&D, is falling in developed countries over time. A decline in research productivity may be a sign of declining returns to R&D through less innovation output in relation to the R&D inputs. This declining research productivity is considered a likely reason for the slow-down in economic growth rates from the 1970s and is an important ingredient in some endogenous growth models (Freeman and Louca, 2001, p. 300, Aghion and Howitt, 1998p. 404). There has been some evidence of a decline in research productivity in the US, the UK, Germany and France over the period 1970–1990 (Kortum, 1993, Griliches, 1990, 1994). Lanjouw and Schankerman (2004) analyse the declining research productivity in the US and found that some (but not all) of it may be explained by increased patent quality over time. Nonetheless, empirical findings from other countries do not speak unambiguously for a decline in research productivity. For example, Ejermo and Kander (2007) showed that Swedish business research productivity did not fall in Sweden after 1985, even before adjusting patents for quality. After quality adjustment, Swedish research productivity was found to be even better. In addition, Madsen (2007) questions the stylized fact of generally declining research productivity in developed countries.

If the paradox originates in weaknesses of the innovation system, something that should concern policy makers, we may expect the gap to be a general phenomenon of the economy. Alternatively, we could expect it to occur in outphasing sectors of the economy, i.e. in sectors with low or even negative growth rates. In such an interpretation, some sectors would lose out since they would lack the capabilities of transforming R&D into value added growth. One would not expect the fast growing parts of the economy to show the largest gap in growth rates of R&D and value added unless economic growth is actually something very resource- intense and there are some marginal decreasing returns. If growth by necessity is R&D-intense these days, then the Swedish paradox should not be a concern. High and increasing R&D is then simply the cost we have to pay to uphold reasonable rates of economic growth, as suggested by Jones (2002).

Alternatively, the idea of marginal falling (patent) returns to R&D may be related to firm size. In Cohen and Klepper (1996), R&D faces diminishing returns and has an associated fixed cost. For large firms, i.e. those with higher output, the returns to R&D are higher for comparable levels of R&D than for firms with lower output. Hence larger firms are better off with more R&D relative to small firms, since their fixed costs can be spread over a larger output. Larger firms therefore have an incentive to conduct more R&D. Large firms, *on the margin,* become less efficient than small firms. In other words, small firms have to come up with more novel ideas since they have to pay for their expensive laboratories or other equipment. Unsuccessful new firms have to exit from the market and are rarely observable in any data sets. This may explain the stylized fact that smaller firms produce a higher share of patents relative to their R&D (Bound et al., 1984).[2]
If the fast-growing sectors of the economy have a larger size of R&D-performing firms than the slow growing sectors, this idea of Klepper may help to explain why fast - growing sectors have poor research productivity. Such size-relationships may of course

[2] It is difficult to get patents granted for incremental, more process-oriented innovations.

result from the fact that they are fast-growing sectors, but they may also be relatively large initially.

The idea that sectors differ with respect to innovation is of course not new. Especially scholars related to SPRU (science and technology policy research at the university of Sussex) such as Pavitt (1984), Freeman and Louçã (2001) and Malerba (2002, 2005) have developed the so called sectoral innovation systems approach and pointed out that sectors differ with respect to 'style' of innovation. Still, sectoral approaches of explaining the Swedish paradox have not yet been used in empirical studies. The aim of this paper is therefore to investigate whether the gap between R&D investments and economic growth is a common feature across sectors of the economy, or whether it is specific to some sectors; either fast-growing or slow-growing sectors. Secondly, we use a modified measure of research productivity (quality-adjusted patents/R&D) to explore whether sectors with a large gap between R&D and value added also have low research productivity. If declining research productivity could serve as an explanation for low growth from the 1970s in general, as suggested by Freeman and Louçã (2001), we would expect slow-growing sectors to have poor research productivity and fast-growing sectors to have good research productivity. If slow- growing sectors do not show inferior research productivity to the fast-growing sectors, we must conclude that we face marginal decreasing returns to R&D in terms of quality adjusted patents, especially in the fast-growing sectors. If so, then the Klepper models on firm size and research productivity are relevant to investigate.

2. Data and method issues

For the purpose of this study, we have merged two databases: DEVIL (Databases of Evolutionary Economic Geography in Lund) and CIDER (CIRCLE Innovation Databases for Economic Research). Thereby, we have obtained firm-specific data on R&D, patents and value added encompassing most commercial activities in Sweden. We have matched patents granted at the European Patent Office 1985-2002and quality indicators of the same patents with the respective firms. We use a basic industry classification of 103 manufacturing and 25 service classes and have reduced the empirical complexity by classifying the industries of our merged database into five broad sectors: fast-growing industries, slow-growing industries, industrial outphasers, fast-growing services and slow-growing services. [3] This taxonomy is largely based on the level of growth rates during the period 1978 to 1998. For the fast-growing and slow-growing industries, however, it is complemented by an examination of relative prices.[4] The method to empirically derive this taxonomy was discussed by Dahmén (1970, 1984), Josefson and Örtengren (1980) and Ljungberg (1990), but was further developed in Svensson Henning (2006) and Lundquist et al. (2008a).

Fast-growing industries are characterized by strong growth in value added with relatively low increases in output prices. In Dahmén's words such industries may be characterized as "market widening". As the name indicates, many of these industries may be regarded as technological leaders, since they open up new producer and consumer markets (Svensson Henning, 2006). The *slow-growing industries* are identified on the basis of two criteria: relative increases in price levels and some growth, but slower growth than the fast-growing industries. The slow-growing industries are characterized by "market suction", to use Dahmén's terminology.[5] Rising demand and inelastic supply lead to rising relative prices of goods produced in these industries. Demand-induced growth may be complementary and induced by the market-widening growth of the fast-growing industries, but does not rely as extensively on front-line technological change in products and production methods. The expansion of slow-growing industries may also be demand-driven by general income increases in the economy. *Outphasing* industries are located on the 'negative' side of economic transformation and are characterized by reductions in value added over time. There may be several reasons for a weak performance of this sector, such as increased foreign competition, substitution effects or market saturation.

[3] For more information about the DEVIL database and the principles for the consistent classification systems, see Lundquist et al. (2005, 2006).
[4] A separate appendix with detailed description of the identification methods may be obtained on request from the authors.
[5] Op cit.

Some of these industries are phased out from global production, but others relocate to other countries due to relatively high costs of production.

For the service sector the typology is based only on growth rates, since reliable price indices are still lacking. We distinguish between fast-growing producer services, labeled *fast-growing services* (Lundquist et al., 2008b) and other services, here called *slow-growing services.*

Research productivity denotes the ratio between patents and R&D, which is an indicator of how many inventions materialize from inventive input. R&D expenditures and patents both have their pros and cons as innovation indicators; R&D expenditures are a measure of the input to the inventive process and do not encompass all such inputs. In particular smaller firms do not have R&D departments and may not fulfil the requirements of doing R&D, in a formal sense. Patent data are based on observed behaviour, are rich in information and come with several quantifiable features. However, all innovations are not protected by patents and sectors have different propensities to patent (Scherer, 1983, Griliches, 1990). Many patents are taken out to pre-empt competition and for other strategic purposes such as to facilitate cross-licensing. Eventually many patents turn out to be financially useless. A better innovation indicator is therefore *Quality-adjusted patents*, which takes the technological impact and economic prospects of the patent into account (Lanjouw and Schankerman, 2004, Ejermo and Kander, 2007).

The study uses R&D expenditures and a variant of research productivity defined as quality adjusted patents divided by R&D expenditures. For quality adjustment of patents we use the following indicators: *forward citations* are the number of citations *to* the patent by subsequent patents, *backward citations* are the number of citations *made* by the patent to previous patents), *family size* shows the number of countries protecting the same patent and *opposition* is a binary variable indicating whether the patent was opposed in court or not. The individual quality indicators also contain time trends, which are not necessarily linked to actual quality changes. For instance, the number of patent offices continually rises, thus increasing *family size*. This is not per se an indication of increasing patent value. Moreover, the number of citations may differ due to the technology of the patent (patenting within certain technologies is more common and patents in those technologies receive more citations). A first necessary step is therefore to filter out trend and technology characteristics. This is done by regressing the indicators on year dummies and technology shares in 30 different technologies. The resulting residuals are used in a factor analysis, which extracts the common factor for the remaining variation of quality indicators. This method therefore implies that *joint* positive developments of the indicators are more likely to indicate better patent quality. A formal explanation of the factor analysis, with equations and tests, is provided in Ejermo and Kander (2007).

To date we can use Quality Adjusted Patent data up to 1998. The reason for this is that an important quality indicator, forward citations, is truncated since citations arrive with time lags.

3. Analyses

Sectoral growth patterns

Table 1 about here.

Table 1 shows the annual growth of fast-growing industries, slow-growing industries and industrial outphasers between 1978 and 1998. Fast-growing industries have experienced strong growth, on average 7.5% per annum. This sector consists of 25 industrial classes dominated by high knowledge intensity[6] (e.g. car bodies and engines, paint, construction machinery and other machinery, engines and turbines) and R&D intensive industries (e.g. pharmaceuticals, industrial process control equipment and telecom) as well as chemical products and sawmilling. Thus, the fast-growing-industries comprise several industries that are intuitively associated with production of the key inputs of the third industrial

[6] This is based on Ohlsson and Vinell (1987) who made a taxonomy of Swedish industries in five factor-dependency categories: R&D intensive, knowledge intensive, capital intensive, labour intensive, and protected from foreign competition.

revolution (such as telecom and control equipment), but also a number of industries that have directly benefited from technical and institutional complementarities with these industries. The fast-growing industries have increased their weight of the total production volume among the manufacturing sectors from 19 to 42 per cent.

Slow-growing industries are much more heterogeneous in terms of production activities than fast-growing industries. They include 46 industries from a broad range of manufacture. Among these we find some of the 'traditional' Swedish manufacturing industries such as pulp and paper, steel, pumps and compressors, machinery, ship engines, rubber, general metalware, electric motors and aircrafts, textiles and furniture. The sector is characterized by substantially lower growth of 0.3 % during the period 1978-1998. Although the slow-growing industries decrease their relative production shares over the period, they still contribute to half of the production volume in 1998.

Industrial outphasers declined from 19% to 9% of total manufacturing value added, with an annual average growth of -1.8%. Examples of industries in this group are electric domestic products, fish products, glass, construction material industries, wearing apparel and footwear. Many of these industries fared fairly well during the inflation-plagued and to some extent sheltered economy of the 1970s and 1980s. However, they were exposed to drastic transformation pressures in the economic crisis of the early 1990s. Even though the outphasers have experienced massive creative destruction and market contraction, segments of these industries still survive due to their ability to renew and engage in specialized niche production, especially in the larger metropolitan regions (Lundquist et al., 2008a). Important to consider regarding this category is that the automotive industry ends up here. It is reasonable that this industry is placed here, because of its diminishing importance in terms of employment and total value added. Some firms in this industry do however have a high profitability, especially in certain years, but the taxonomy does not take this into account. The automotive industry is responsible for a large part of all R&D and patenting activities in this sector.

Table 2 about here

Table 2 shows the growth performance of the two service categories between 1985 and 2004. The fast-growing producer services consist of four service classes (1) IT-service; (2) marketing, advertising, design and management consulting; (3) R&D labs; and (4) security services. IT services together with marketing, advertising, design and consulting have experienced the fastest growth. Generally speaking, fast-growing producer services deal with theoretical tasksand provide high knowledge- and information services to manufacturing and other sectors (Lundquist et al., 2008b).

Slow-growing services consist of four producer service classes: (1) leasing and industry-related machinery/equipment; (2) finance and legal services; (3) technical/engineering consultancy; (4) industry related wholesale, as well as all consumer and general services. The classes included here are very mixed with regard to their knowledge intensity. The growth is fair (2.6 per cent per annum 1985-2004), but not near that of fast-growing services (9.8%).

The fast-growing sectors in industries and services grow substantially faster than the remainder of the economy and are the foundations of the economic growth in this period. Without them, growth would most certainly have been much slower. Our next section is directed to the connection between this growth taxonomy and the innovative efforts in the different industries.

R&D and Patenting

Swedish R&D increases from 13.7 billion SEK in 1985 to 61.4 billion in 1998 in constant prices (Table 3). This drastic increase is not unique to Sweden, although Sweden stands out as one of the top nations in terms of R&D expenditures in relation to GDP (Ejermo and Kander, 2007). As expected, there is a very high concentration of R&D to some specific industries. If we take the R&D expenditures of 371 SNI92 classes (the earlier version of the Swedish adaptation of NACE-codes), we find that the Hirschmann-

Herfindahl index (HHI)[7] is 0.37 in 1991, but increases to 0.55 in 1998 (and 0.67 in 2002). This indicates that R&D expenditures become more concentrated to certain industries during our period of investigation.

Inspection of the division of R&D expenditures among our sectors shows that fast-growing industries, slow-growing industries and industrial outphasers spend about equally much on R&D in 1985. After the international financial crisis of the early 1990s, a dramatic divergence occurs in R&D expenses. By 1998, fast-growing industries accounts for about two thirds of R&D expenses in manufacturing.

Services have experienced dramatic growth of R&D expenses since the mid-1980s. Part of this may be due to poor reporting of actual expenses in the early years. Together, services accounted for about 15% of total R&D expenditures in 1998. Fast-growing producer services and slow growing services each accounted for slightly higher R&D expenditures than industrial outphasers that year. The growing share of R&D in services, and especially the fast-growing producer services, indicates that this is an increasingly important sector for R&D activities in times of extensive corporate outsourcing and ever-increasing development of knowledge-intensive business services (KIBS).

Table 3 about here

To complement this picture, the number of granted patents per sector is also summarized in Table 3. The total number of granted patents each year is rather small. However, the number increases from 409 in 1985 to 906 in 1998 (122%). Concentration of patents is generally low; 0.03 as measured by the Hirschmann-Herfindahl index, applied to the 371

[7] The HHI measure is: $HHI = \sum s_i^2$, where s_i is the share of R&D-expenditures in industry i. Total dispersion would imply that an infinite number of industries have equal shares, a figure that approaches zero, and hence the measure becomes zero. On the other end of the scale, when just one industry has all the activity, the measure takes the value 1.

SNI92 classes in manufacturing and services. This indicates a much flatter distribution of patenting activity than R&D expenditures among the different industries.

Fast-growing industries and Slow-growing industries are by far the most important sectors when it comes to patenting. Fast-growing industries also increase their annual patenting dramatically from 104 to 366. The slow-growing industries also have a fair share of the patents, especially in the mid-1990s. To our surprise, the number of patents among slow-growing producer services is fairly large and exceeds by far that of fast-growing producer services.

Sectors differ in their propensity to conduct formal R&D and to patent. This is illustrated in Table 4. In 1985, R&D expenditures in relation to value added were highest for Fast-growing industries and, more surprisingly, for Outphasers. Slow-growing industries had a lower ratioand services reported very small R&D expenditures at the beginning of the period, with the ratio close to 0 %. The levels of patents to R&D were the highest in services followed by Slow-growing industries and Fast-growing industries. Outphasers clearly had the lowest level of patents to R&D.

Table 4 about here.

The gap between R&D and value added

Figure 1 about here.

Figure 1 shows R&D, value added and quality adjusted patents to R&D for the fast-growing industries. There is a clear gap between R&D and value added over time. Indeed, the winners are, by conventional measures, poor performers in relation to their R&D investments. This may possibly be explained by a substantially better research productivity in this sector than other sectors. However, the research productivity, indicated by the quality-adjusted patents to R&D, is not very impressive, but shows a small increase towards the end of the investigated period. So the Paradox is manifest in the fast- growing industry.

Figure 2 about here

The slow-growing industries exhibit a markedly different path than that of the Fast-growing industries (Figure 2). R&D expenditures are fairly constant with business-cycle like variations, but there is no clear increasing or decreasing trend. Economic growth does take place, but at a slow rate. There is no apparent gap between R&D and value added, and thus no paradox here. Rather, both R&D and value added grow slowly. For the slow-growing industries, quality-adjusted-patents per R&D expenditures increases dramatically towards the end of the period, something very different from the fast growing industries. This relatively more impressive increase in research productivity, as compared to the fast-growing industries, takes place from higher initial levels in 1985, so it is not a matter of catch-up with the fast-growing industries. Slow-growing industries actually get more quality adjusted patents out of their R&D. This means that we do not find slow growth being caused by poor research productivity, which may seem startling, but one possible explanation is that the slow-growing industries are not as seriously affected by uncertainty in very early development and implementation of new technologies as the fast-growing industries. Another possibility is that firms may, on average, be smaller in this group and thus the Klepper (1996) model would help to explain the results. Still, what stands out is that losers in terms of economic growth perform well with respect to R&D (no gap between growth of value added and R&D) and in terms of research productivity.

Figure 3 about here

For industrial outphasers we find, as expected, that R&D and value added both decline over time (Figure 3). However, there is no apparent gap between the two, which is a similar observation to the one made for the slow-growing industries; thus no paradox here either. Patents are very concentrated to a few industries of the outphasers (HHI=0.69 for the whole period) and the increasing patenting towards the end of the period are mainly driven by four large firms. Quite surprisingly, outphasers substantially increase research productivity (quality adjusted patents/R&D) over time, even more so than slow-growing industries, but unlike slow-growing industries, outphasers started out at a very low level in 1985, which means that the process may be perceived of as a catch up towards levels of fast- and slow-growing industries for segments of the outphasers industries. If firms are small in this group compared to fast-growing industries, the Klepper (1996) model would assist in explaining these results.

Figure 4 about here

Turning to the fast-growing service sector, we find a large growth gap between R&D and value added (Figure 4). This resembles the gap for fast-growing industry, but is far more pronounced. Thus we see the Paradox again being manifest in the fast-growing parts of the economy. The R&D expenditures for this group started at very low values in 1985, after which a very dramatic increase took place until 1996. Some of this increase is most likely due to underreporting in the early years. However, the R&D expenses of the sector still only amounts to about 7% of total R&D in the business sector in 1998. As previously mentioned, R&D laboratories are included in this group, which suggests that the steep increase of R&D is partly an effect of corporate outsourcing from traditional manufacturing firms. Research productivity declines by a factor of 100 over this period, as an effect of the steep increase in reported R&D. Value added increases 3.8 times.

Figure 5 about here

Slow growing services had no apparent gap between value added and R&D until 1992, after which R&D took off in a very steep manner. Thus there is some Paradox prevalent in this sector, but not as clear cut as for the Fast growing services. However, one must remember that R&D started at very low levels and in 1998 slow-growing services accounted for only 7.5% of total R&D in the business sector. Research productivity grows until 1992 when it drops to lower levels. Again, this means that we see the negative relation between Paradox and research productivity, and therefore it makes sense to look at the firm size once again to see if it was larger after 1992 than before.

Patenting relative to R&D on the firm level

It may seem puzzling that less-R&D-intensive sectors seem to have higher amounts of patenting relative to their R&D. Some of the differences in patenting seem possible to explain by the models outlined by Klepper (1996) and Cohen and Klepper (1996) as discussed in the introduction. To start with, consider Figure 6 below.

Figure 6 about here.

Figure 1 shows that there is an empirical observable regularity between the ratio of patents to R&D to log R&D levels as found earlier by e.g. Bound et al. (1984). Figures 2-3 show similar patterns, but now subdividing among the five different sectors.

Figure 7 about here.

Figure 8 about here.

It therefore seems possible that part of the observed high research productivity in less successful sectors when it comes to economic growth, may be explained by the amount of R&D in different firms. In other words, is it possible that the amount of R&D in less progressive sectors is, on average, less per firm, due to smaller sized firms being more common there? To examine this, Figures 4-5 plot the average amount of R&D done by R&D performing firms in the different groups 1-5.

Figure 9 about here.

Figure 10 about here.

These figures give partial corroboration of the idea that the ratio can be explained by the average amount of R&D of firms. For fast-growing industries, the average amount of R&D is generally high. This is paired by a slowly increasing ratio of quality-adjusted patents to R&D. For slow-growing industries, the average amount of R&D done is low, but the ratio of quality-adjusted patents to R&D increases dramatically over time. For Industrial outphasers, there is generally high average R&D while a sharp increase in quality-adjusted patents to R&D takes place at the same time. Therefore, this group does not seem to follow the predicted pattern. However, as previously reported, this group may be somewhat of an exception where a few influential automotive firms are responsible for most of the R&D and patenting taking place. For fast-growing services there is a high average amount of R&D coupled with a low ratio. Finally, slow-growing services have a low average R&D and a low ratio. To conclude, the Klepper models seem to predict patterns among groups 1-2 and 4, but are less successful in groups 3 and 5.

4. Conclusions and suggestions for further research

In relation to the Swedish Paradox our results suggest that fast-growing sectors are mainly responsible for the gap between growth rates for R&D and value added. The paradox is thus not a feature of the entire economy, but rather of a group of technologically progressive industries. The paradox is not the effect of poor performance in slow-growing sectors of the economy, where no ‘paradoxic’ effects could be found. Therefore, the paradox should, at least in the medium term, rather be interpreted as a sign of success and as an effect of progressive industries making extensive investments in

R&D. Perhaps we should talk about the blessings of the Swedish paradox instead, since without the contemporaneous performance and investments of the fast-growing industries and fast-growing services Swedish economic growth in this period would have been a true disaster. With regard to policy implications, we could argue that economic growth is costly and requires large R&D expenditures with very long-term expected pay-off. There is probably no shortcut to this.

A limitation of our study is that R&D that takes place in Sweden may have positive effects on production in other countries, since Sweden has unusually many multinational enterprises. Thereby, R&D effects are not solely captured by the Swedish value added data that this study utilizes.

Research productivity, here measured as quality adjusted patents to R&D ratios, also differs markedly among sectors. The levels in 1985 were already very different and service sectors are generally more productive than industrial sectors as they get more patents out of their R&D expenditures. Another interesting result is that the slow-growing industries have a much higher level of patents/R&D than fast-growing industries. Both slow-growing industries (from high initial levels) and Outphasers (from low initial levels) show substantial improvements in research productivity and thus have a much better performance than the two fast-growing sectors. A partial explanation for the better research productivity for slow-growing industries and Outphasers may be that these sectors are more path dependent and more risk averse in their R&D investments. They proceed along their technological trajectories, while the fast-growing industries pave new ways. The models suggested in Cohen and Klepper (1996) and Klepper (1996) go some way towards explaining the results, since there is a negative relationship between research productivity and R&D expenditures. This indicates that research productivity is subject to diminishing returns. An in-depth analysis of that framework requires a well specified econometric analysis, which falls outside the scope of this paper. In addition, it would be desirable to divide R&D into process and product R&D in order to distinguish more clearly any scale effects, as predicted by the models, but such data are rarely available in practice.

We conclude that the progressive and fast growing sectors were ‘saviours’ of the Swedish economy in this period and accounted for the Swedish paradox. By conventional short-term measures, they were also poor performers with respect to research productivity. This reinforces the conclusion that economic growth requires large and long-term R&D efforts and that there are diminishing returns to R&D for the fast-growing parts of the economy. This in turn is partly explained by the Klepper (1996) model and the fact that these sectors have larger firms. Over the very long run we will see declining growth rates in R&D investment, since there are limits to the share of the workforce that can be assigned to R&D tasks. This may, however, lead to changing relative prices acting as a pull towards more effective organization of R&D and innovative activities, so the decline in growth rates that eventually must come, if Jones (2002) is right, may be postponed and is not yet in sight. The R&D show must go on.

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Tables and Figures

Table 1. Shares of value added of manufacturing and annual growth of fast-growing industries, slow-growing industries and industrial outphasers 1978-1998.

Group	**No of industrial classes (version of SNI69)**	**Annual growth 1978-1998 (%), value added,[8]**	**Share of total value added of manufacturing 1978 (%)[9]**	**Share of total value added of manufacturing 1998 (%)[10]**
Fast-growing industries	25	7.5	19	42
Slow- growing industries	46	0.3	62	49
Industrial outphasers	32	-1.8	19	9
Total	103	2.5	100	100

Source: Elaboration from Svensson Henning (2006).

[8] Value added, measured in constant prices.
[9] Measured in nominal prices.
[10] Measured in nominal prices.

Table 2: Production values in the service sector

Sector	**Annual growth, 1985-1994, % volume**[11]	**Annual growth, 1994-2004, % volume**[12]	**Annual growth, 1985-2004, % volume**[13]
Fast-growing producer services	9.5	10	9.8
Slow-growing services	2.2	3	2.6
Total services	2.7	4	3.4

Source: own calculations from DEVIL database and Lundquist et al. (2006).

[11] Approximated value added Lundquist et al. (2006), deflated with Consumer Price Index.
[12] ibid.
[13] ibid.

Table 3. Number of granted patents, R&D in constant prices, 1985 year level, million SEK.

		1985	1990	1995	1998
Fast-growing industries	patents	104	148	280	366
	R&D	5.0	8.6	23.0	40.7
Slow-growing Industries	patents	174	187	305	274
	R&D	4.1	5.9	9.0	7.7
Industrial outphasers	patents	17	38	31	73
	R&D	4.0	10.2	9.1	4.1
Fast-growing services	patents	35	22	33	44
	R&D	0.01	0.8	3.4	4.4
Slow-growing services	patents	79	117	180	150
	R&D	0.5	0.9	2.5	4.6
Total	patents	409	512	829	906
	R&D	13.7	26.4	47.0	61.4

Note: The nominal costs for R&D have been deflated with a wage series for graduate engineers, Ljungberg (2006).

Table 4. Patents/R&D ratio, R&D/Value added ratio, in 1985.

	Patents/R&D	R&D/value added
Fast-growing industries	20.8	10.5%
Slow-growing industries	42.1	3.2%
Industrial outphasers	4.3	10.9%
Fast-growing services	98	0%
Slow-growing services	153	0.2%

Figure 1. R&D, Value added and Research productivity for Fast-growing Industries

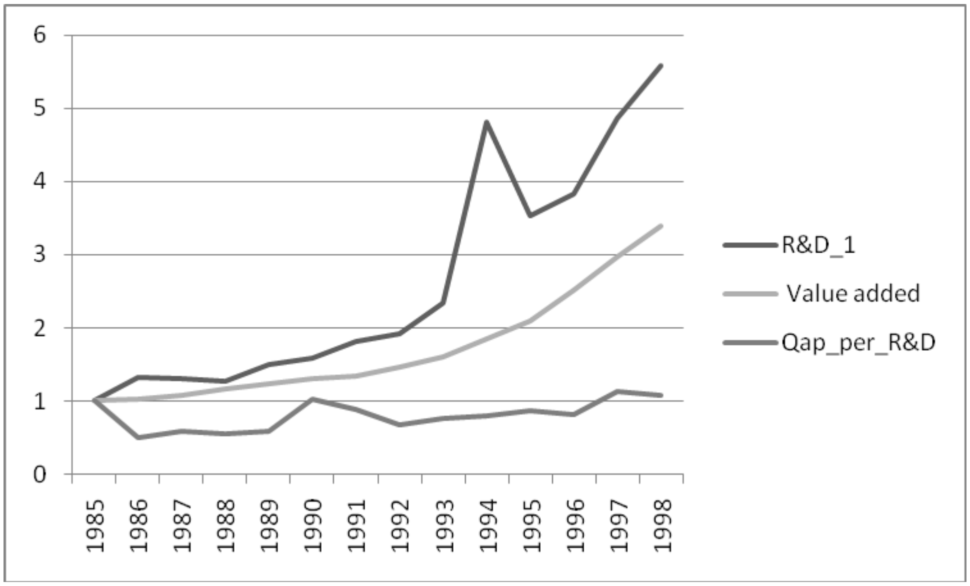

Figure 2. R&D, Value added and Research productivity for Slow-growing Industries

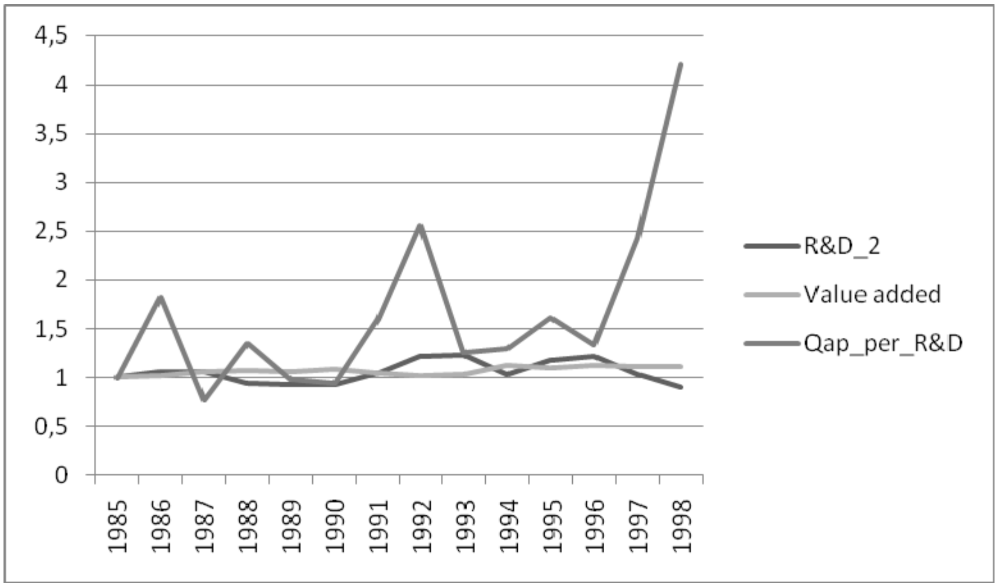

Figure 3. R&D, Value added and Research productivity for Industrial outphasers

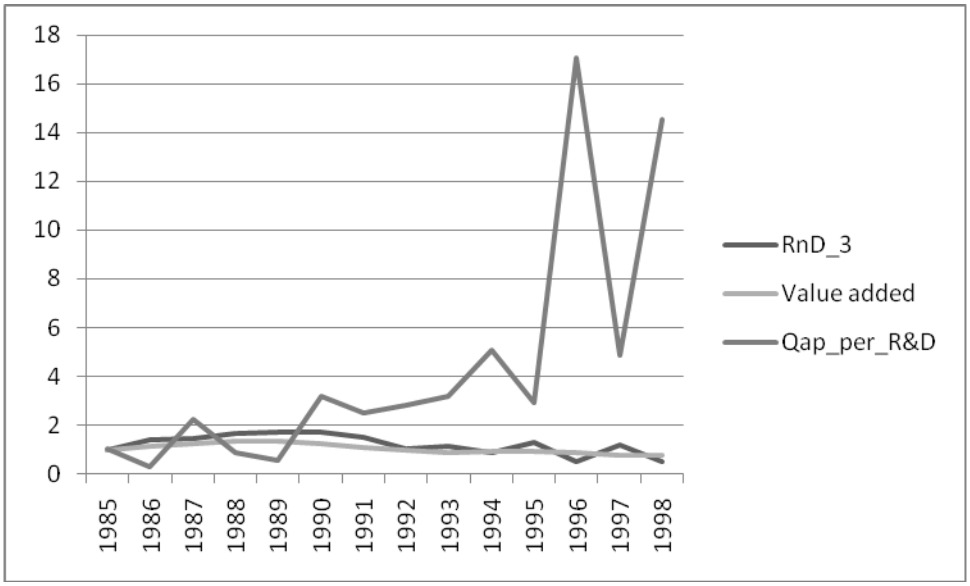

Figure 4. R&D, Value added and Research productivity for Fast-growing services

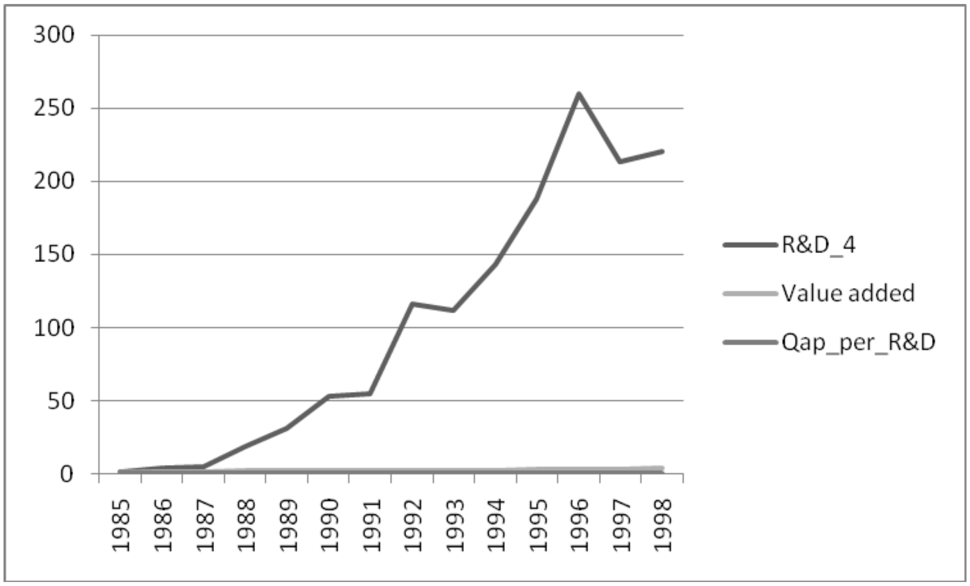

Figure 5. R&D, Value added and Research productivity for Slow-growing services

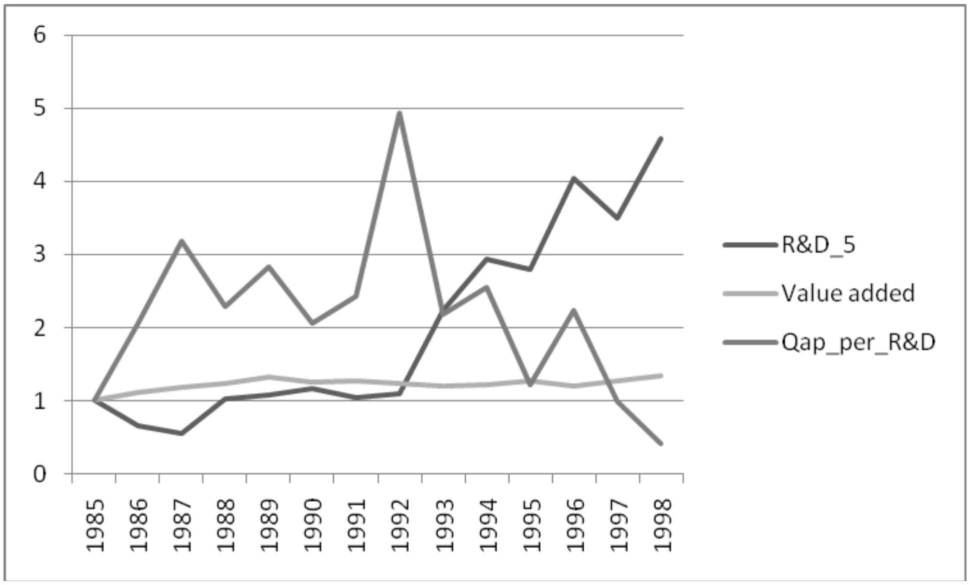

Figure 6 Log R&D and patents to R&D, averages 1985-1998 for all firms.

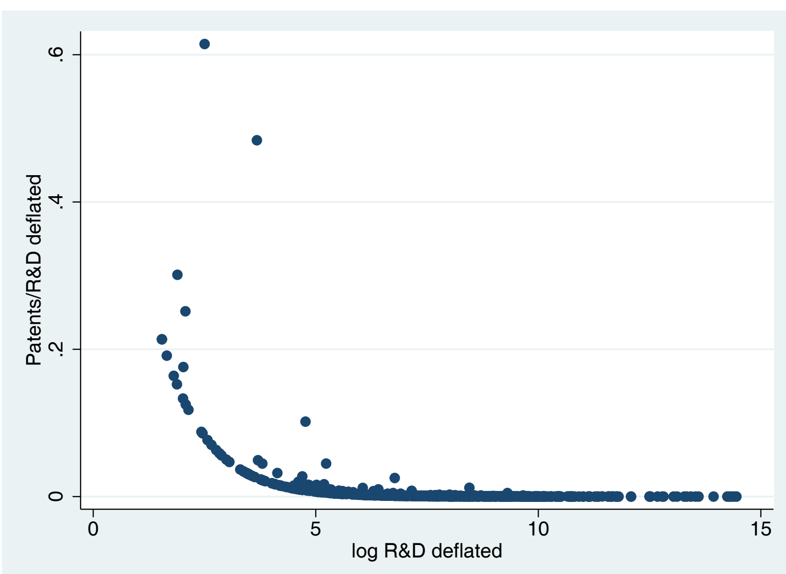

Figure 7. Log R&D and patents to R&D, averages 1985-1998 for firms in fast-growing industries, slow-growing industries and outphasers.

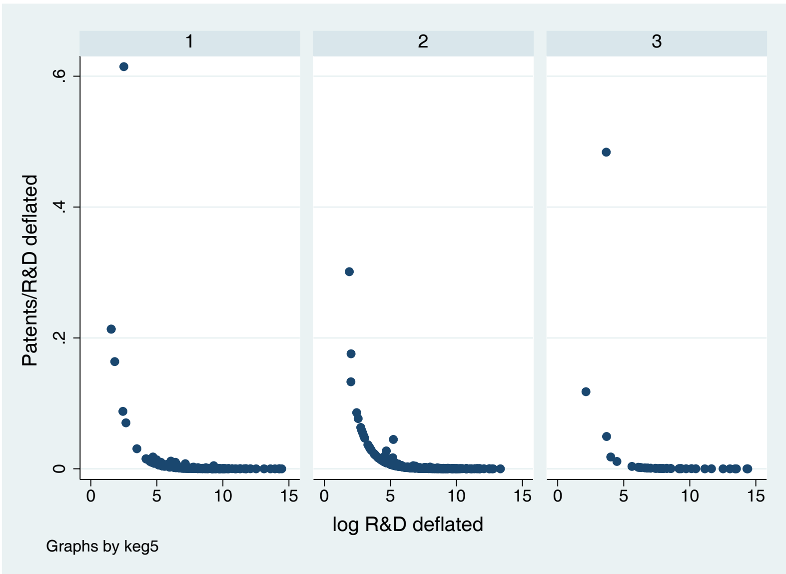

Figure 8. Log R&D and patents to R&D, averages 1985-1998 for firms in fast-growing services and slow-growing services.

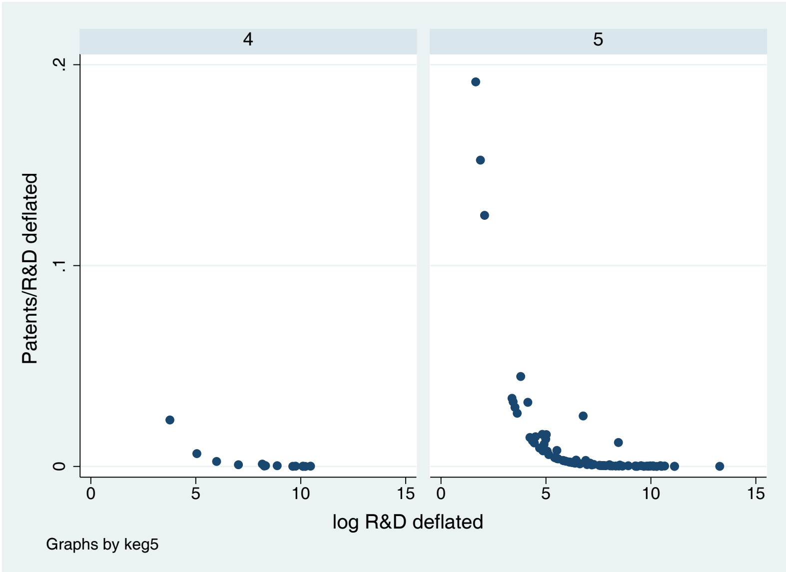

Figure 9. Average R&D 1985-1998 for R&D-performing firms in fast-growing industries, slow-growing industries and outphasers .

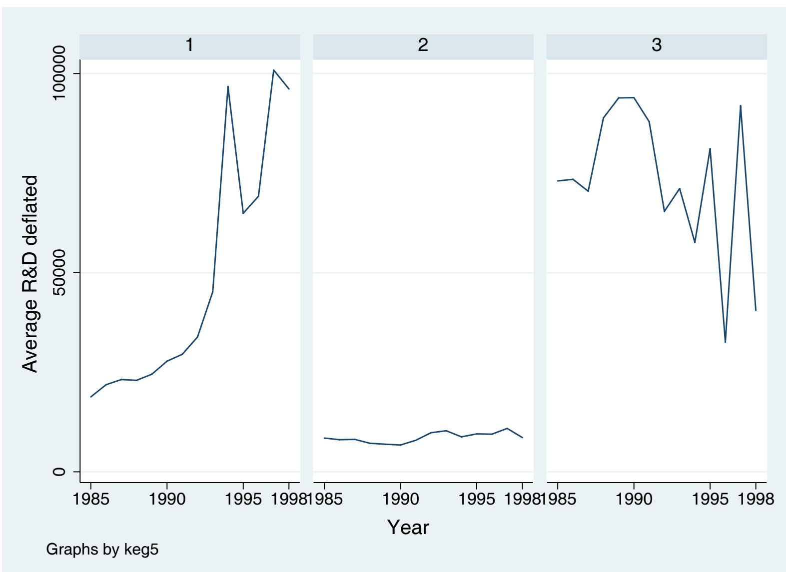

Figure 10. Average R&D 1985-1998 for firms in fast-growing services and slow-growing services.

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