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Trends in R&D, innovation and productivity in Sweden 1985-2002

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Abstract

We use a new, comprehensive database covering Swedish industry and service firms 1985-2002, to examine trends in the ratio between patenting and R&D (PR-ratio). There is a fall in PR-ratios in the long run (1985-2002) on the aggregate level and for all sectors. In general low-tech sectors perform better in terms of PR-ratios than high-tech sectors. A fall in the PR-ratio could be offset by increasing patent quality. We use two indicators of quality in this paper: forward citations and family size. The quality-adjusted PR-ratios also fall in the long run, but unlike the raw PR-ratio that falls drastically after 1997, the fall only takes place in the first half of the period (1985-1994), and then levels out. There is thus strong correlation between the Swedish economic growth performance and the quality-adjusted PR-ratios. The trend in the quality adjusted PR-ratio is mainly driven by the Paper, pulp and paper products industry together with R&D in science, engineering and medicine. We find high correlation between quality-adjusted-patents and R&D at the sector level, but not between quality-adjusted-patents and growth in value added or labour productivity.

Keywords: patents, quality-adjustment, R&D, time trends, productivity

1 Introduction

Sweden is one of the most business R&D-intensive countries in the world, but notions of the Swedish paradox question the efficiency of this R&D in generating innovations (Ejermo and Kander, 2006). This paper sheds light on the innovative outcome of Swedish R&D, based on a new, rich database. First, we examine trends and trend breaks in patents in relation to R&D at the aggregate level and then using a 10 sector level division. Second, we use quality adjusted patents to examine whether these trends have been offset by a change in the quality of patents. Third, we investigate the correlation between quality adjusted patents and growth in these sectors.

2 Previous studies

Research productivity as measured by the ratio of patents to R&D (the PR-ratio) has declined sharply in many countries and industries over the last decades. Between 1970 and 1990 the number of patents produced per US scientists and engineers nearly halved, and in Europe the decline has been even more striking (Evenson, 1984, 1993). This has motivated attempts to sort out the reasons behind the decline, while maintaining a sectoral perspective. Lanjouw and Schankerman (2004) present an interesting effort in this direction. They suggest four potential reasons for a decline in the PR-ratio over time:

1) *Declining propensity to patent.* Different sectors protect innovations by various means and patenting is only one option. For instance, many firms in the 1993 Community Innovation Survey report that secrecy is a more important appropriation mechanism than patenting (Arundel, 2001). The PR-ratio in a sector may change over time if the propensity to patent shows a time trend, which could result from rising costs of patenting relative to other protection measures (Cohen et al., 2000).

2) *Decreasing returns to R&D*. Given the neoclassical assumption of decreasing marginal returns, a decline in the PR-ratio can simply be due to a substantial increase in R&D. Such an increase in total R&D has taken place because companies have increased their R&D investments in response to increased private returns as markets expand. However it has been demonstrated that this effect is not large enough to explain the entire decline (Evenson, 1993, Kortum, 1993).

3) *Technological exhaustion*. If inventors have already come up with the best ideas, perhaps innovations are in the process of becoming exhausted. This is a very gloomy outlook, which has not been confirmed by econometric estimates of output elasticities of R&D (Hall, 1993a, Hall, 1993b, Griliches, 1994).

4) *Improved patent quality*. In contrast to the technological exhaustion idea, newer patents may be more valuable, since new ideas build upon previous ones. This would suggest that increasing quality of patents may compensate for lower quantity. It is also the explanation that Lanjouw and Schankerman (2004) address. They construct a four component composite index of patent quality for the US 1980-1993 based on:

a) Claims: the principle claims of a patent define the essential novel features of the invention
b) Backward citations: number of prior patents cited in the application.
c) Forward citations: all subsequent patents that cite a given patent in their application.

d) Family size: the number of patents protecting the same invention in different countries

Claims and Family size are regarded as the indicators that best show the economic value of the patent, while Forward Citations and Backward Citations better show technological diffusion. In the quality index of our paper we use only two of these factors: Forward citations (Trajtenberg, 1990) and Family size (Putnam, 1996). We cannot use Claims, although relevant, since data on claims are not available for European patents.

Lanjouw and Schankerman (2004) use a full dataset on patents applied for by US firms in the period 1975-1993, totaling 434 108 patents. For a subset of firms (unclear how many) they have data on annual R&D expenditures, sales, capital stocks and market value. Firms and patents are classified following seven technology areas: drugs, biotech, other health, chemicals, computers, electronics and mechanical. They assess to what extent increased patent quality can explain the decline in research productivity (i.e. the PR-ratio) from 1980 to 1993 in the US. The answer partly depends on technology area. In drugs, quality improvement does not compensate for the fall in the PR-ratio. In two sectors quality improvements are important for offsetting the decline in the PR-ratio; in chemicals the decline is reduced from 20% to 7%, in the mechanical field from 40% to 29%. In "other health" and electronics there was no fall in research productivity in the first place, with quality adjustment the PR-ratio actually increases.

The US has experienced a "patent explosion" already since 1984 (Kortum and Lerner, 1999, 2003, Hall, 2005). That research does not explicitly address the development of the PR-ratio, but it seems possible that the declining trend of the PR-ratio might have come to a halt at some point. We study an extended period for Sweden, one that continues beyond 1993.
The "explosion" in US patenting has been concentrated in the electrical, electronics, computing and scientific instruments industries. Patents became more likely to be upheld in litigation, with big penalties for infringers, implying that firms considered patenting more cost-worthy. In addition patents were used for cross-licensing and trading/negotiation with other firms in complex products, and for securing finance for startups (Cohen et al., 2000). With the rich data we have for Sweden we are able to compare sectoral patent behaviour between sectors and with the same sectors in the US.

The original studies by Schmookler (1966) and Griliches (1984) assigned patents to industries and firms respectively, but did not assess patent quality. The use of quality adjusters and the validation of these measures is a more recent phenomenon. Most of these studies use indirect validation techniques, e.g. expert appraisal of innovations, and stock market value of patenting companies (Trajtenberg, 1990, Lanjouw et al., 1998, Harhoff et al., 1999, Jaffe and Trajtenberg, 2002, Harhoff et al., 2003, Lanjouw and Schankerman, 2004, Hall et al., 2005, Hall and Trajtenberg, 2005). Trajtenberg (1990) related patents in computed tomography (medical technology) to the estimated social surplus, and found no correlation for raw patents but did for citation-weighed patents. Harhoff et al. (1999) asked German patent holders to estimate a price at which they would have been willing to sell the patent right, and find correlation between this price and subsequent citations. Questionnaires sent to inventors and managers about the values of individual patents give direct validation (Gambardella et al., 2005). For a large sample Hall et al. (2005) find correlation between the stock market valuation of publicly traded firms and the "patent citations/patent"-ratio over the period 1976-1995. Stock market valuation, however, is a highly volatile measure, sensitive to expectations and not an objective measure of actual economic performance of firms. Therefore an alternative validation procedure is to compare the evolution of labour productivity and the labour force (together making the growth of the company) with the quality adjusted patents. In this paper, which is mainly interested in broad trends, we will merely examine simple correlations between labour productivity, R&D and patenting, postponing econometric models to a later paper where we make full use of our individual firm data.

3 Data

We use a new, rich database consisting of R&D and labour productivity for all Swedish firms over the period 1985-2002 that has been compiled by Statistics Sweden for a group of researchers at Lund University (Lundquist et al. (2005, 2006).

To this database we have matched on patents from the European Patent Office (EPO), with computerized assistance from Statistics Sweden and a company specializing in name-matching (IRIS). This was a time-consuming work where we matched names and addresses of applicants with firms in our database. The matching process conducted by IRIS yielded suggested 'hits' for individual patent applicants that we had to control. In many cases more than one firm was selected as a possible candidate for matching and we had to choose the best hit. Statistics on this matching is given in Appendix A. The basis for selecting the patent data was that the creative act of inventing had been done by a Swedish person, i.e. among the inventors we find at least one person registered as a resident in Sweden. We used fractional counting, further described in Appendix A.
We deleted 4,794 Swedish individuals (5,027 when including also non-Swedish) from our material. This procedure left us with initially 19,082 applications made by Swedish applicants in the 1985-2002 period, whereof 9,549 were granted. Of these applications we managed to match 14,460 applications (76%) and 6,822 grants (71%) to the exact year. However, our matching revealed that we had found matches also with firms not present in our data base for the *exact* year. The reason why firm data was missing for certain years rests in sampling, where especially smaller firms may not always be covered before 1996. Since our purpose was to examine sectoral patterns, we apportioned the patent to the sector of the firm from the closest year at hand. This raised our "matching-rate" to 17,382 applications and 8,722 grants, or 91% for both as a share of all applications and grants when excluding individuals. Although we regard this result as highly successful, we were concerned that the matching-ratio could differ over the time-period under study. Indeed, our data confirmed that the matching-ratio was much higher in the latter part of the period under study. Among applications, the ratio for which we obtained a sector for patents was 73% in 1985 and 89% in 2002 (95% was obtained for some years). Apart from the database containing all firms since 1996, it seems likely that the reason why we got better matching rates towards the end of the period is because

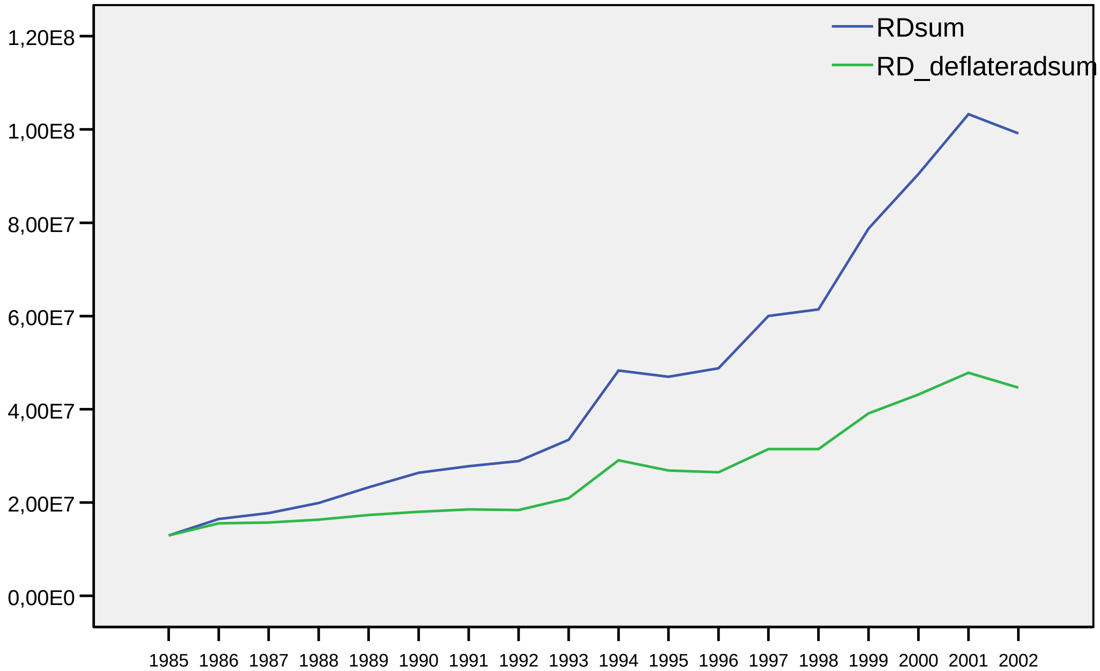
patent registers are continuously updated, whereas firm registers are not. We chose therefore to adjust the patent figures in each sector proportionally to the inverse of the matched ratio for individual years. This means that we remove the time trends imposed because of differing matching rates, which is crucial for the objective of this paper.

The end-result is a database consisting of most Swedish firms from 1996 onwards, both in industry and services, and all large firms 1985-1995 together with a sample of smaller firms.[1] Only a small fraction of the firms perform any R&D at all, or submit patent applications, and the ratio is much smaller in service sectors than in industry.
There were roughly 5,000 industrial firms in the database per year 1985-1995, but from 1996 and onwards the number increased to roughly 35,000, due to a fuller inclusion of smaller firms. Likewise for the service sector the firms increase from roughly 10,000 to around 250,000 between 1995 and 1996. This could pose a major problem for our investigation. However this is not the case, since only a minor fraction of the smaller firms that were added in 1996 do R&D. Actually, aggregate R&D in industry falls between 1995 and 1996, while there is a small increase in the service sector.

We think there are two substantial strengths of our material. First, our material comprises almost all Swedish firms that patents and/or do R&D, thus obtaining a high match-ratio good overall coverage. Second, we were able to cover a fairly long period of time for such a material (1985-2002). Our material covers a unique 3,490 firms, or an average of 392 firms per year, that conducts R&D and/or patents. As a comparison, the famous Hall, Jaffe and Trajtenberg data-set for the US matched patents over a long time-period 1965-1995 but 'only' reached a match-ratio of 50-65% (depending on year). Their material covered an average of 1,700 manufacturing firms per year (or 4,864 in total) using data on firms listed in Compustat. Figure 1 shows that the annual sum of firm-based R&D grows substantially over time.

[1] 1985-1995 industrial firms with less than 15 employees and service firms with less than 50 employees are only partially included in the material, but 1996 onwards the coverage of small companies is nearly complete.

Figure 1. Sum of R&D, current and constant prices, 1985 price level, 1000 SEK.



In this first paper exploring the database, we concentrate on the sectoral level and examine the broad developments and characteristics of R&D, patenting and 'quality adjusted' patenting. We intend in full to explore the micro-characteristics (firm-level) properties of our data to estimate fully-fledged econometric models in future work.

4 Sectoral division and quality-adjustment of patents

4.1 Sectoral division

For many reasons it turned out to be wise to use a rather broad sectoral division. One reason was the change of industry-classification in Sweden in the period from SNI69 to SNI92. Using rather aggregate sectors removes much of comparability problems over time. Moreover, finer divisions that we originally used, yielded very little R&D and/or patenting for certain sectors. We chose only to present 10 sectors in the end, a division that we have labeled CIRCLE10. The logic was to keep technology-intensive sectors separate from less intensive ones. At the same time we wanted to keep manufacturing and service sectors apart. The exact division is given in Appendix B. There are 7 sectors in manufacturing and 3 in services. CIRCLE1 consists of low- and medium-technology intensive manufacturing industries and primary sectors. CIRCLE2-CIRCLE7 are high-technology intensive manufacturing sectors. CIRCLE8 consists of low- and medium-technology intensive service sectors, and CIRCLE9-CIRCLE10 are high-technology intensive service sectors.

R&D expenditures need to be deflated to facilitate comparison with patents. Since civil engineers are an important part of the work force in research, we chose to use the wage index for this group as our R&D deflator.[2]

In order to calculate the labour productivity at the sector level we use sector specific producer price indices, most of which were available from the homepages of Statistics Sweden. For pharmaceuticals, which are dominated by just a few firms, we signed a confidentiality agreement with Statistics Sweden in order to obtain the series and are not allowed to disclose certain data for this sector. To obtain a time-series for the entire period we linked together series based on SNI69 with SPIN2002. For service sectors no producer price indices exist, so labour productivity was only calculated for CIRCLE2-CIRCLE7.

4.2 Quality-adjustment of patents

The quality adjusted patent indices are made up of two components: citation-weighed patent grants and family-size weighed patent grants. These values (aggregate and for each sector) are normalized to 100 each in 1985. These values are below denoted $citations1985$ and $famsize1985$ respectively. The index for a particular year t was then constructed as:

$$index_t = \alpha \cdot citations1985_t + (1-\alpha) \cdot famsize1985_t$$

Our base case was to give citations and family size equal weight ($\alpha = 0.5$), and we made sensitivity analysis by using $\alpha = 0.2$ and $\alpha = 0.8$. The results are reported on in 5.2.

[2] The wage series for civil engineers was provided by Jonas Ljungberg and elaborated for Ljungberg (2006).

Table 1. Our division of the material into sectors and R&D in patenting in those sectors (after adjustment – see section 3 for details).

CIRCLE10	Technology level (L=low, M=medium, H=high), manufacturing (M)/service (S)	Short description	Sum R&D (deflated) 1985-2002	Sum patent applications (after adjustment) 1985-2002	Sum patent grants (after adjustment) 1985-2002
1	L&M, M	See Appendix B	23,740,352	2,270	1,313
2	H, M	Pulp, paper and paper products	9,028,886	602	396
3	H, M	Chemical products (excl pharma)	9,248,588	578	366
4	H, M	Pharmaceutical related products	60,519,120	927	454
5	H, M	Machinery and equipment n.e.c.	41,601,882	2,841	1,707
6	H, M	Electrical, electronics and precision equipment	174,899,411	5,545	2,099
7	H, M	Transport vehicles and equipment	102,822,394	1,218	743
8	L&M, S	See Appendix B	16,398,849	3,445	1,797
9	H, S	communications	17,212,778	568	165
10	H, S	R&D in science, engineering, and medicine	16,680,860	1,087	508

5 Results

5.1 Raw patents and R&D

Figure 2 shows the number of Swedish patent applications and granted patents in relation to R&D. The trends are declining as in many other countries and the result is thus according to our expectations. There was no change in this pattern beyond 1993 In addition, there are also cyclical patterns, with a slump in 1993-1994 and a peak in 1996 (grants) and 1998 (applications). This cyclical pattern fits partly with the development of GDP, with a severe recession in 1991-1993 and negative growth. The continued fall in grants after 1996 is more difficult to relate to overall growth, since GDP grew by an annual 3.0% 1993-2002.

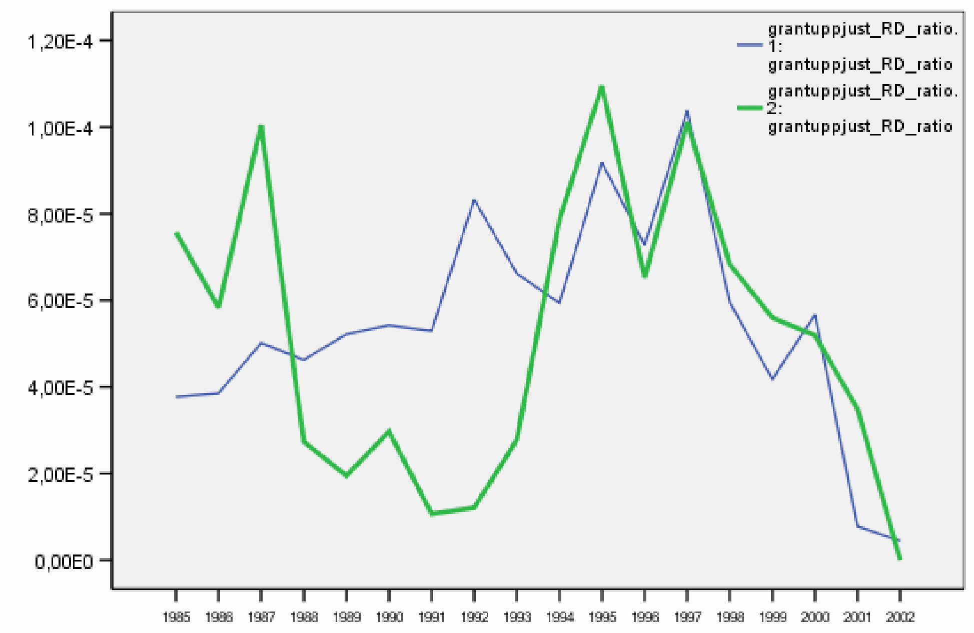
The decline in applications and grants is partly due to time lags in patent handling, but to some degree reflects an actual decline in applications and grants. We follow the recommendations by OECD (2005) that citations can be used until 1999. We further suspect that there might be some problems with the patent application and grant data in the last years of the period, and are hence somewhat careful in our conclusions. We await an updated version of the EPO-database issued in 2006.

Figure 2. Swedish patent applications and granted patents in relation to R&D.

For sectors, we show the results in three separate graphs (Figure 3-Figure 5). Analysing them makes it possible to discern which sectors are particularly important for shaping the

aggregate curve and which sectors deviate from the general development. The overall impression is that sectors vary a lot in their PR-ratio evolution, and thus play different roles for shaping the aggregate graph.
Figure 3 shows two sectors that only display cyclical patterns, and no time trend. These are the industrial- low and medium technology (ILM) sector and Pulp, paper and paper products. While Pulp, paper and paper products shows a very strong business-cyclical pattern, much stronger than the overall economy, and reacting immediately to the crises and recovery (see Figure 2), the ILM sector fluctuates less, and rather shows an increasing trend until 1998, followed by a substantial drop.

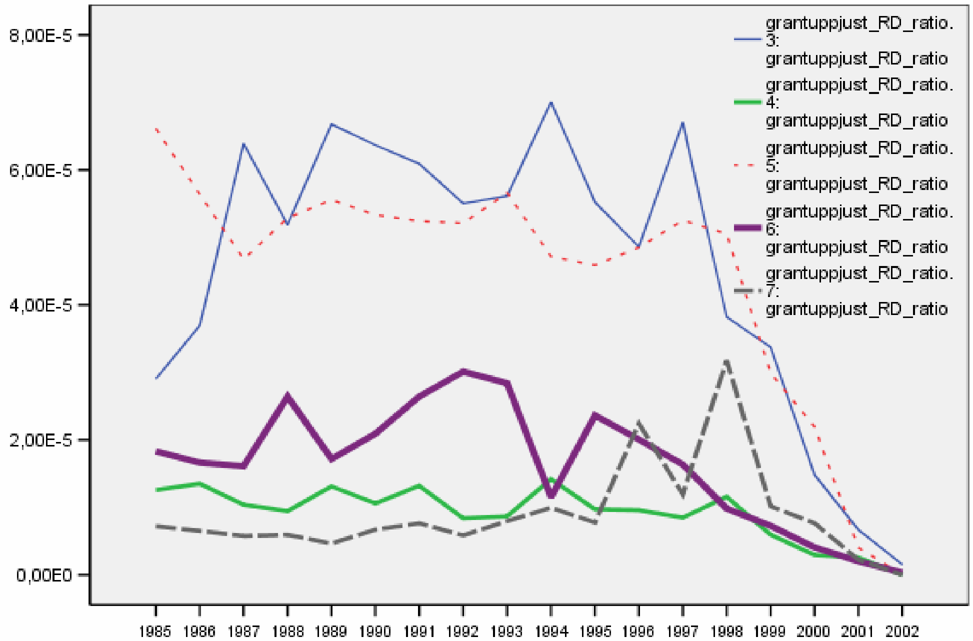
Figure 3. Number of patents in relation to R&D in industrial- low and medium technology sectors (#1) and Pulp, paper and paper products (#2).



In Figure 4 we find five technology-intensive industries. A somewhat startling result from comparing levels of grants to R&D is that sectors 3 and 5 (Chemistry and Machinery equipment n.e.c.) are relatively more productive in patenting than their related sub-sectors 4 and 6 (Drugs and Electrical-and-Electronics). Sectors 3 and 5 are counter-cyclical to each other up until 1997, but show no time trend, and then there is a drastic drop in both series.

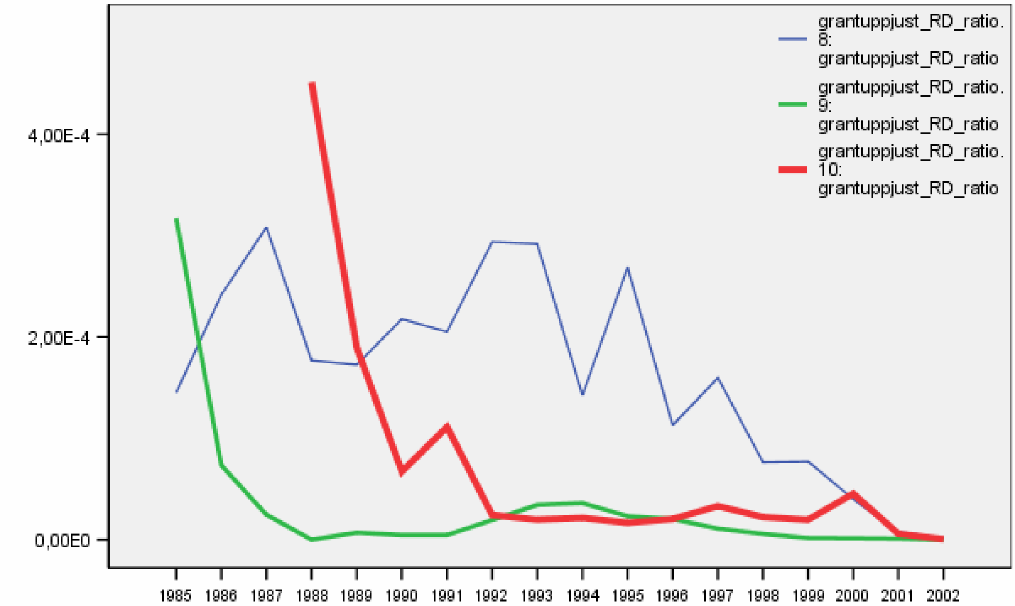
The trend of the Electrical-and-Electronics-sector (#6) is one of falling since 1992, with a temporary hike in 1995. Thus there does not seem to have been a similar patenting boom in this sector in Sweden as there was in the same sector in the US (Hall, 2005). The pharmaceutical sector (#4) has the most stable PR-ratio. The ratio is low with an only modestly falling trend. Transport vehicles and equipment (#7) goes against the overall falling trend, showing a modestly increasing ratio 1985-1998, after which it falls in line with all the other sectors.

Figure 4. Number of patents in relation to R&D in 5 industrial sectors: chemical products (excl. pharmaceuticals) (#3), pharmaceutical related products (#4), machinery and equipment n.e.c. (#5), electrical, electronics and precision equipment (#6) and transport vehicles and equipment (#7).



In the service sectors (Figure 5) we find a different time pattern than in the industrial sectors. Two sectors, Communications (#9) and R&D in science, engineering, and medicine (#10), both fall drastically in the beginning of the period, and then level out, while the low- and medium-technology service sectors (#8) show no particular time trend until 1993, after which the ratio falls. It is noteworthy that the service sectors are more efficient than the industrial sectors in relation to its R&D (the scale on the Y-axis is 10 times larger in Figure 5). Since also the industrial- low and medium technology sectors (#1) had high levels of grants in relation to R&D, we draw the conclusion that the low-medium tech sectors as a group are more productive than the high-tech sectors in terms of patents.

Figure 5. Number of patents in relation to R&D in 3 service sectors: service sector at low- and medium-technology levels (#7), communications (#8) and R&D in science, engineering and medicine (#9).



5.2 Accounting for patent quality – does it matter?

One basic method for evaluating the quality of patent applications is naturally to see if they were granted or not. Consequently we can draw some general conclusions on the quality evolution of Swedish patent applications simply by looking at the gap between applications and granted patents in Figure 2. This gap is rather constant 1985-1989, it narrows 1989-1995, but then a larger share of applications are not being granted. Thus there is no simple quality improvement over time in this respect.

A more elaborated procedure is to weigh patents by quality. Such quality indices in relation to R&D-expenditures are shown in Figure 6. As explained in 4.2, the indices build on forward citations and family size. Three indices putting increasingly higher weight to family size are used.
While family size on average increases over time, quite the opposite happens to the forward citations: there is a drastic drop over time. This is not reported by Lanjouw and Schankerman (2004) for their US material.[3] It would be interesting to know whether this is something unique for Sweden or applies for other countries as well. Backward citations decline per patent in the EPO material ever since 1978 and it would not be surprising if that goes for forward citations as well, but it needs to be investigated (OECD, 2005). As a consequence of the falling number of forward citations, regardless of the relative weight given to the two components in the index, the Swedish data does not show increasing patent quality over time (Figure 6). Later research may reveal whether decreasing returns to R&D, technological exhaustion and/or declining propensity to patent can explain the falling trends.

[3] Patents filed at the USPTO have many more citation than their EPO counterparts. This is due to stronger requirements on US applicants to list all previous patents of relevance. According to EPO a good search report contains all relevant information within a minimum number of citations (Michel and Bettels, 2001).

The decline is not as large when patents have been quality adjusted (Figure 2 and Figure 6). The timing is very different though. While the major decline takes place before 1994 for quality adjusted patents, the decline for raw grants takes place thereafter. This means that the output of high-quality patents was falling dramatically 1989-1994, which might have contributed to the economic recession. In the period of economic recovery, after 1994, there was a stable flow of quality adjusted patents in relation to R&D, but at a much lower level than in the beginning of the period.

Figure 6. Quality adjusted patents in relation to R&D. The top line puts the highest weight to family size, the lowest to forward citations.

It is of interest to see in what sectors the decline is particularly strong before 1994. Figure 7 demonstrates that Paper, pulp and paper products (#2) clearly contributes to the fall.

Figure 7. Quality adjusted patents per R&D in industrial- low and medium technology sectors (#1) and Pulp, paper and paper products (#2).

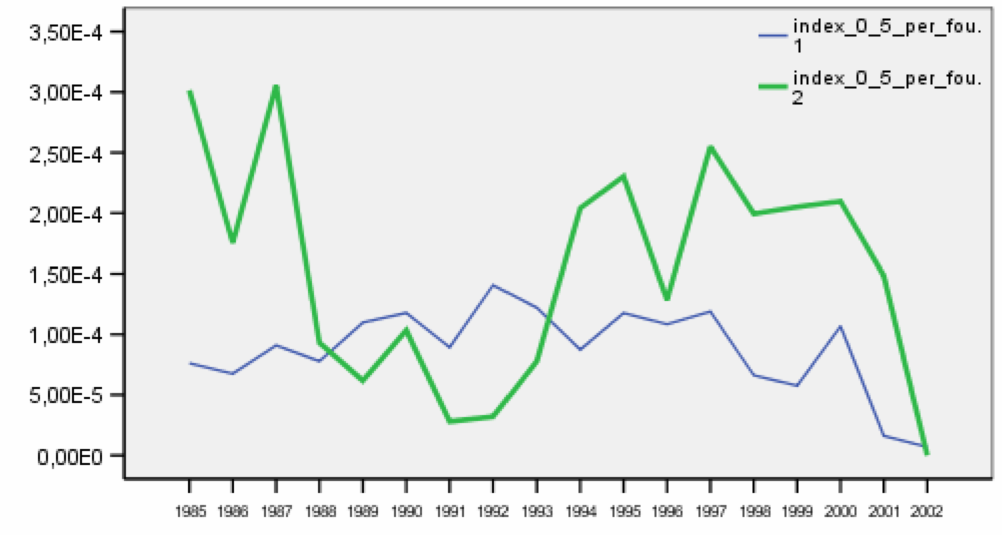
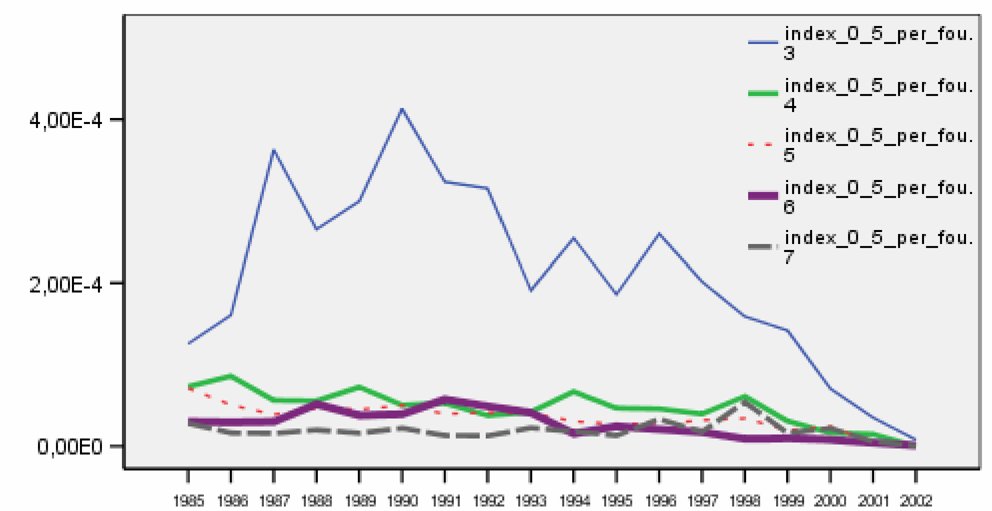


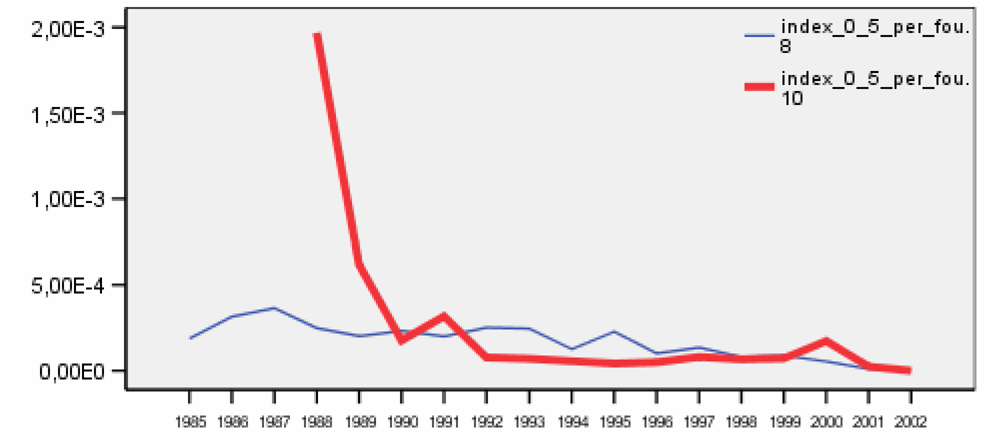
Figure 8 shows that Chemistry (#3) has a very different evolution compared to the entire economy. It grows until 1990 and then declines. Pharmaceuticals (#4) does not change much if we quality adjust or not, just like in the US case. Machinery n.e.c. (#5) changes fundamentally from the quality-adjustment (cf. Figure 4): from being a sector of high output (similar to Chemistry). It falls to a level close to the one of sectors 4, 6 and 7. Electrical, electronics and precision equipment (#6) shows a rather even trend and so does Transport vehicles and equipment (#7). Of the industrial sectors it is thus only Paper, pulp and paper products (#2) that contributes to the substantial fall in patent quality the beginning of the period.

Figure 8. Quality adjusted patents per R&D in 5 industrial sectors: chemical products (#3), pharmaceutical related products (#4), machinery and equipment n.e.c. (#5), electrical, electronics and precision equipment (#6) and transport vehicles and equipment (#7).



For service sectors, shown in Figure 9, R&D in science, engineering and medicine has a dramatically falling patenting quality in the beginning of the period. Sector 9, communications, vanishes from the graph completely, since their patents never received any citations. In conclusion, it seems like two sectors affected the initial fall in the overall quality adjusted patents to R&D: Paper, pulp and paper products (#2) and R&D in science, engineering and medicine (#10). Most sectors had a stable ratio after 1994.

Figure 9. Quality adjusted patents per R&D in 2 service sectors: LMS (#8) and R&D in science, engineering and medicine (#10).



5.3 R&D, patents and productivity

A stylized fact is that there is higher correlation between R&D and growth or labour productivity than between patents and growth or labour productivity (Pakes, 1985, Cockburn and Griliches, 1988, Klette and Kortum, 2004). A reasonable hypothesis is that quality adjusted patents will show better correlation with labour productivity and/or growth in value added than raw patents. Testing this thoroughly requires econometric analysis, which is best done on the micro-level, and this is beyond the scope of this paper. We here only examine the mean over time of sectors of value added and value added per employee vs. mean of R&D, and quality adjusted patent grants.

Visual examination of these correlations (available upon request) reveals that there is virtually neither any correlation between R&D and value added / VA per employee, nor between quality adjusted patents and VA or VA per employee. However, quality adjusted patents and R&D has a clearly positive correlation.

6 Concluding discussion

This paper relies on a new database covering the entire Swedish economy at the firm level 1985-2002, with variables of value added, employees, R&D and patents with quality information. The research questions are: 1) Whether patents/R&D ratios decline in the long-run, 2) If patents become more valuable over time and 3) If there is any

correlation between quality adjusted patents and some objective measure of economic performance such as value added or value added per worker.
The results are partly similar and partly different to the results based on US data (Lanjouw and Schankerman, 2004, Hall et al., 2005).

Swedish data confirms that there is a fall in PR-ratios in the long run (1985-2002) on the aggregate level and also for the 10 sectors.

The quality of Swedish patents seems to be falling over time in contrast to the quality of US patents. We use two quality indicators: forward citations and family size as the two components of our quality index. While family size (the number of countries protecting the same patent) grows as a consequence of more countries becoming member of the EPO, forward citations per patent drops substantially. This means that the hypothesis of increasing patent quality compensating for declining quantity (in relation to R&D) is not confirmed in the Swedish case, as it was for some sectors in the US. An important issue is whether it is appropriate to use forward citations as a quality measure at all for longitudinal studies. Could it be the that citations per patent increase in the US over time, but not in Europe, simply due to the different citation praxis by USPTO and EPO highlighted by Michel and Bettels (2001)? As a result of the poor quality development of Swedish patents the aggregate quality-adjusted-patents/R&D-ratio also falls in the long run, but unlike the ratio of raw patents/R&D that falls drastically after 1997, the fall only takes place in the first half of the period (1985-1994), and then levels out. The trend in quality adjusted patents/R&D is mainly driven by the Paper, pulp and paper products industry together with R&D in science, engineering and medicine.

We found no correlation between quality adjusted patents and value added (or value added per worker), but strong correlation between R&D and quality adjusted patents. This issue awaits more rigorous tests at the micro-level.

Appendix A: Statistics on matched patent applications

We did not count number of patent applications, but rather patent application fractions. Among the *applicants* of a patent, there may be non-Swedish ones. Moreover, we found that many applicants were actually individuals and not firms. Individuals were never counted as part of a patent, since we consider only patents matched to firms. In addition, non-Swedish applicants were excluded, but they were included among the total number of applicants for the purpose of counting fractions, unless they were individuals. A “complicated” example should make this clear. Patent A has five applicants: two Swedish individuals, two Swedish companies, one Danish individual and one Danish company. Excluding all individuals leaves us with three applicants to the patent, whereof Swedish firms are given 2/3 of the patent.

The following table shows some data described in the text on how many patents were matched. “Fully matched patents” refer to patents that were matched to a firm in the correct year. “Matched to sectors” refer to patents that could be matched to a sector also including matches to the right firm, but taking data on sector from a different year. This column shows the material that is later used for our sectoral analysis.

Table 2. Data on matched patent data.

	All patents excl. individuals		**Fully matched patents**		**Matched to sectors**	
	Applications	*Grants*	*Applications*	*Grants*	*Applications*	*Grants*
1985-2002	19 082	9 549	14 460	6 822	17 382	8 722
Share of all excl. individuals	*100%*	*100%*	*76%*	*71%*	*91%*	*91%*

Appendix B: Sector division ("CIRCLE10") used in the paper

CIRCLE 1: Low- and Medium-technology-intensive manufacturing sectors (LM) and in addition primary sectors.

Agriculture, forestry, hunting and fishing, extraction, mining and quarrying of natural resources (gas, oil, minerals, peat etc.), food products, beverage and tobacco industry, textiles, clothing and leather, wood, cork, wood products, publishing, printing and reproduction of recorded media, industries for coke and petroleum products, rubber and plastics products, other non-metallic mineral products, basic metals, fabricated metal products, building and repairing of ships and boats

CIRCLE 2: High-technology intensive in manufacturing (HM); "Pulp, paper and paper products"

CIRCLE 3: High-technology intensive in manufacturing (HM); "Chemical products"

CIRCLE 4: High-technology intensive in manufacturing (HM); "Pharmaceutical related products"

CIRCLE 5: High-technology intensive in manufacturing (HM); "Machinery and equipment n.e.c."

CIRCLE 6: High-technology intensive in manufacturing (HM); "Electrical and electronic equipment, and precision equipment"

Office machinery and computers, electrical machinery and apparatus n.e.c., radio, television and communication equipment and apparatus, precision, medical and optical instruments

CIRCLE 7: High-technology intensive in manufacturing (HM); “Transport means”

Motor vehicles, trailers and semi-trailers, railroad equipment and transport equipment, n.e.c., aircraft and spacecraft

CIRCLE 8: Low- and Medium-technology-intensive service sectors (LMS)

Manufacture of furniture; manufacturing n.e.c.; recycling, rental of machinery and leasing, financial and legal services, technical consultants, commercial/advertising, organizational and design consultants, wholesale - production oriented, management of real estate, security, sales of food products, tobacco and beverages; department stores and warehouses, consumer durables, wholesale - consumer oriented, recreation and cultural services, other personal services, education, research in social sciences and humanities, healthcare, other social activities (daycare, criminals, etc.), public administration, police, defence, banking and insurance, restaurants and hotels, activities of membership organizations, embassies and international organizations, cleaning; sewage and refuse disposal, sanitation and similar activities, sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel, electricity, gas, steam and water, construction

CIRCLE 9: High-technology intensive in services (HS); “communications”

Data and IT services; communication incl. transportation, postal services, telecommunication

CIRCLE 10: High-technology intensive services (HS); “Research within science, engineering, and medicine”

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