R&D, patenting and patent quality in Sweden 1985-2002[1]

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Abstract

We use a comprehensive database covering Swedish industry and service firms 1985-1998, to examine trends in the ratio between patenting and R&D and for patenting quality among 10 sectors which cover almost the entire economy. Quality indices are composed of the indicators forward and backward citations, designated states and opposition. In contrast to earlier studies we find forward citations and opposition to have the highest weight in our indices.

Swedish data indicate no clear trend in patenting patenting/R&D ratios over the period 1985-2002 on the aggregate level. During the same period Swedish R&D has been rising fast. Among low- and medium tech manufactures, chemicals and transport vehicles and equipment R&D levels remain fairly constant. Patenting productivity and associated quality seems to be fairly high, However, quality seems to be lagging somewhat in low- and medium tech industries and transport vehicles and equipment. The fastest rise in R&D in absolute terms is seen in Electrical, electronics and precision equipment. Interestingly, this development is not associated with a loss in patenting productivity nor in patenting quality. There are also strong developments of R&D in services, which comprise telecom services, and also in R&D in engineering, science and medicine. The first signals strong investments of telecommunications services industries in Sweden and the second may be a consequence of outsourcing and developments of supporting knowledge-intensive business services. Patenting remains low, which may reflect that these sectors have less patentable inventions.

Our findings are therefore not supportive of the existence of 'the Swedish paradox'.

Keywords: R&D, patenting, quality-adjustment, Sweden, sectors.

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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, 2007). This paper sheds light on the innovative outcome of Swedish R&D, based on a database of Swedish firms which has been matched with European Patent Office (EPO) patent data by us.

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, Evenson, 1993). This has motivated attempts to sort out the reasons behind the decline, while maintaining a technological 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 one of many. 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 expenditures in response to increased private returns as markets expand (Klepper, 1996). 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

In their paper, 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. We obtained data on forward citations (*FCIT*), Backward citations (*BCIT*), Family size or designated states (*DCST*) in the European case, and opposition (*OPPOSITION*), which shows whether the granted patent was 'attacked' in court.

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 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" since 1984 (Kortum and Lerner, 1999, Kortum and Lerner, 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).

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. He found no correlation with raw patents but found that citation-weighed patents were correlated. 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, as in 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.

The paper proceeds as follows. First, we examine trends and trend breaks in patents in relation to R&D at the aggregate level and then use a 10 sector level division. Second, we use quality adjusted patents to examine whether trends are changed by adjusting patents for quality.have been offset by a change in the quality of patents. We investigate the different weight that quality indicators take for different sectors and finally we draw conclusions.

2 Data material

Our database consists of firm level data over the period 1985-2002 of which we use R&D data and sectoral codes in this paper. This data has been compiled by Statistics Sweden for a group of researchers at Lund University (Lundquist et al., 2005, Lundquist et al., 2006).

To this database we have matched on patents from the European Patent Office (EPO). Our indicators of quality, *FCIT, BCIT* and *OPPOSITION* are from a DVD compiled by the OECD and documented in Webb et al. (2005)[3] We added information on *DCST* as our fourth indicator from the webpages of Espacenet. We considered a patent Swedish if one of the inventors had a Swedish address. We had Statistics Sweden and a subcontractor (IRIS) to them helping us with the computerized matching. This work was complemented with time-consuming work by us to manually match names and addresses of applicants with firms in our database. Statistics on this matching is given in Appendix A. We used fractional counting, further described in Appendix A.
We deleted 4,794 Swedish firms owned by individuals which proved virtually impossible to match (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 14,433 applications (76%) to the exact year. However, our matching revealed that we had found matches also with firms not present in our database 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 17,453 applications and 11,223 grants, or 91% and 92% for applications and grants respectively 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 74% in 1985 and 93% in 2002 (95% was obtained for some years). One reason could be that the database contains a much higher share of all existing firms since 1996, but it also 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

[3] The version we use was distributed late 2006.

remove the time trends imposed because of differing matching rates, which is crucial for the objective of this paper.

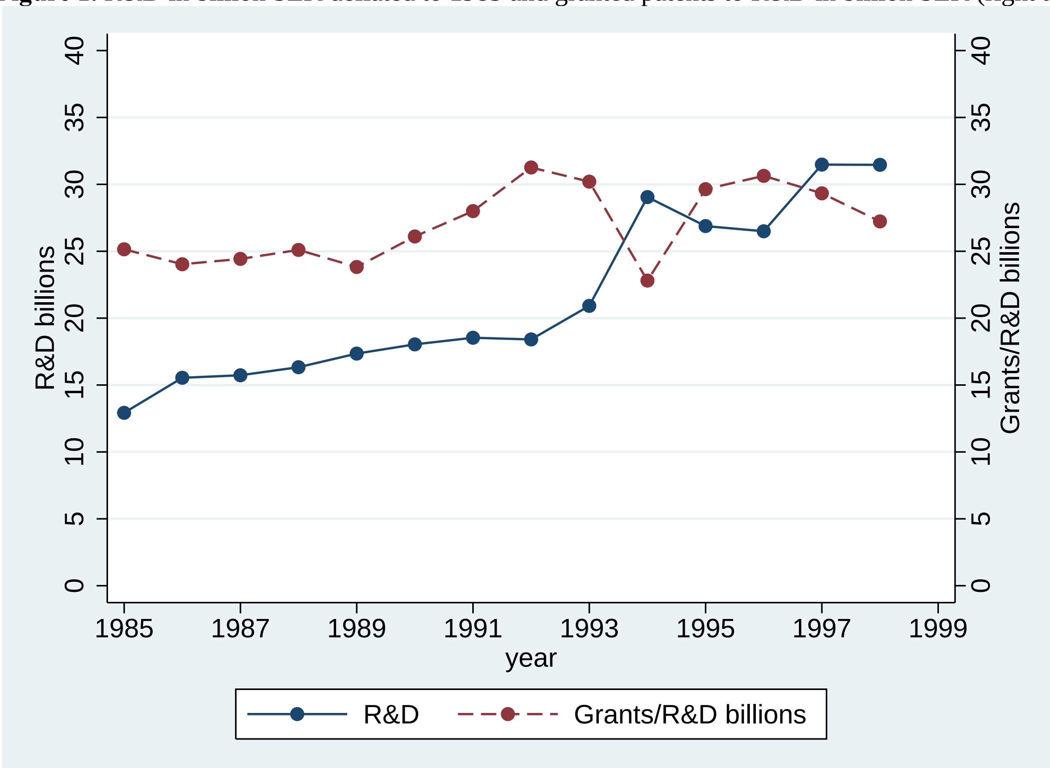
The end-result is a database consisting of most Swedish firms from 1996 onwards, both in industry and services, and all large firms 1985-1995 together with a sample of smaller firms.[4] Only a small fraction of the firms perform any R&D at all, or submit patent applications, and the ratio is much smaller in service sectors than in industry.
There were roughly 5,000 industrial firms in the database per year 1985-1995. 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 does not seem to be 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.

Our material comprises almost all Swedish firms that patent and/or do R&D. Thus, we obtained a high match-ratio and good overall coverage. We were also able to cover a fairly long period of time for such a material (1985-2002). For our quality indicators we choose to use and report data only for the period 1985-1998 since patents granted after 1998 are substantially less cited than earlier ones, which would distort our variable *FCIT*. Our material covers 3,490 individual firms, or an average of 392 per year, that conducts R&D and/or patents. As a comparison, the comprehensive Hall, Jaffe and Trajtenberg database 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. Our R&D data has been deflated by a wage index of civil engineers.

Figure 1 shows aggregated deflated R&D and the ratio between granted patents and R&D ratio among Swedish firms 1985-2002. This graph indicates a different pattern from the experience of the US. Although Swedish R&D has also risen fast, the overall trend in the ratio between granted patents and R&D shows no clear trend.

[4] 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. R&D in billion SEK deflated to 1985 and granted patents to R&D in billion SEK (right axis).



3 Sectoral division and quality-adjustment of patents

3.1 Sectoral division

We divided our material into rather broad groups. A reason for this is a change in sectoral classification in Sweden from SNI69 to SNI92.[5] Using rather aggregate sectors removes much of comparability problems over time. An additional advantage of this is that problems of arbitrary reclassifications of firms across sectors are reduced. Moreover, finer divisions that we originally used yielded very little R&D and/or patenting for certain sectors. The economy is here composed of 10 sectors. Our logic has been to keep R&D-intensive, i.e. OECD "high-tech" sectors separate from less intensive ones and to keep manufacturing sectors separate from service sectors. 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

[5] These classifications closely correspond to ISIC rev 2 and ISIC rev 3 respectively.

index for this group as our R&D deflator which was used in Ljungberg (2006). Table 1 provides summary statistics on granted patents and R&D across our 10 sectors. The five highest average patenting rates over 1985-2002 (in increasing order) are found in the groups low- and medium-tech manufacturers, machinery and equipment not elsewhere classified, low- and medium-tech services and in electrical, electronics and precision equipment. Low- and medium-tech groups get high patenting rates not because they are technologically advanced, but because we aggregate many different industries to these groups. Most R&D 1985-2002 is performed by low- and medium-tech manufacturers, pharmaceutical related products, machinery and equipment n.e.c., pharmaceutical related products, transport vehicles and equipment and in electrical, electronics and precision equipment.

3.2 The quality of Swedish patents

As describe above we compose quality indices on our patent data based on *FCIT*, *BCIT*, *DCST* and *OPPOSITION*. The method follows that of Lanjouw and Schankerman (2004), Gambardella, et al. (2005) and Mariani and Romanelli (2006). There are time trends in our indicators, from which it is not clear whether they represent actual quality changes. In addition, the quality indicators are likely to be influenced by the share of patents in different technologies. To remove these effects we first regress the log of our indicators on yearly time dummies and dummies representing the technologies patents belong to[6]:

(1) $$y_{ki} = \sum_j \beta_j x_{ji} + u_{ki},$$

where *i* referes to the *i*th observation, y_{ki} is the *k*th indicator in logs.[7] The residuals of the four indicators, u_{ki}, are used to form a component according to:

(2) $$u_{ki} = \lambda_k q_i + \varepsilon_{ki},$$

where q_i is the component normalized to have unit mean and zero variance, λ_k are loading factors. The covariance matrix of the residuals u_k is written:

(3) $$\Lambda = E[yy'] = \lambda\lambda' + \Phi$$

The matrix Φ represents the covariance between the ε terms. It is assumed diagonal. The common component is estimated by iterated maximum likelihood which involves estimating the parameters λ_k and σ_k^2 that makes the theoretical covariance matrix as closely as possible resemble the observed correlation structure.

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[6] There are 30 technology dummies based on the technology classification originally developed by HINZE, S., REISS, T. & SCHMOCH, U. (1997) Statistical Analysis on the Distance Between Fields of Technology. Fraunhofer-Institute Systems and Innovation Research (ISI): Karlsruhe.

[7] We have zero values among our indicators and therefore used the transformation (1+log $y_{ki} = (1 + \log Y_{ki})$) for the *k*th indicator.

From estimation of (1) it is found that year and time dummies are each always jointly significant respectively, thus validating their inclusion.

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

No.	Tech. level (L=low, M=medium, H=high), manufacturing (M)/service (S)	Short description of main industries	Sum patent grants (after adjustment) 1985-2002				Sum R&D (deflated), billion SEK 1985-2002			
			Min	Avg	Max	SD	Min	Avg	Max	SD
1	L&M, M	See Appendix B	25,0	78,0	128,5	30,5	1,4	2,2	3,2	0,5
2	H, M	Pulp, paper and paper products	4,0	24,2	42,5	11,1	0,5	0,9	1,4	0,3
3	H, M	Chemical products (excl pharma)	1,0	19,3	25,2	5,8	0,4	0,8	1,8	0,4
4	H, M	Pharmaceutical related products	10,0	27,0	63,5	14,5	1,4	6,1	13,7	4,5
5	H, M	Machinery and equipment n.e.c.	30,0	95,8	128,0	22,3	1,4	3,9	8,7	1,7
6	H, M	Electrical, electronics and precision equipment	37,0	140,8	261,0	77,0	3,3	17,9	44,1	14,2
7	H, M	Transport vehicles and equipment	15,0	45,9	88,5	23,2	3,6	9,7	27,0	5,6
8	L&M, S	See Appendix B	15,0	101,3	157,3	38,6	0,3	1,6	4,8	1,3
9	H, S	Service communication	0,0	11,9	36,0	12,4	0,0	1,9	4,7	1,8
10	H, S	R&D in science, engineering, and medicine	13,0	31,0	61,5	12,0	0,0	1,8	4,8	1,6

The quality component is given by:

$$E[\mathbf{q} \mid \mathbf{y}] = \boldsymbol{\lambda}' \boldsymbol{\Lambda}^{-1} \boldsymbol{\lambda} \quad (4)$$

Since we have logged our indicators, we took the antilog of the above calculated values to form our quality indices. This is necessary since we would otherwise sum negative quality values when examining time trends.

Table 2 shows the correlation matrix of the residuals obtained from the quality indicators pooling all patent data.

Table 2. Correlation matrix of residuals from quality indicators.

	FCIT	*BCIT*	*DCST*	*OPPOSITION*
FCIT	1			
BCIT	0.0470	1		
DCST	0.0735	0.0140	1	
OPPOSITION	0.0956	0.0081	0.0333	1

The results of the one factor model for the pooled model and the individual sectors are presented in Table 3. The one factor model could not be estimated for the groups 2: Pulp, paper and paper products nor 4: Pharmaceutical related products, since Heywood solutions or boundary solutions were obtained. In those cases, factor loadings for *OPPOSITION* and *BCIT* was 1 and there were negative factor loadings for other variables. We therefore chose not to present results for those sectors. From Table 3 we also find negative loadings on the variable *DCST* for sector 10: "Research within science, engineering, and medicine". These results are inconsistent with our theory that all indicators are positively related to the common factor. Since the results are not formally wrong we include them for completeness, but ask the reader to gauge those results with caution.

Normally a χ^2 test is done to test the suitability of the estimated model, but that test is best suited to samples of 75-200 observations; for our larger samples, the χ^2 test has too strong power. Instead, the row RMSEA(2) displays the results of Root Mean Square Error Approximation tests, which is a test on the suitability of the estimated model which can be used for larger samples (Bollen and Long, 1993). This test is written:

$$RMSEA = \sqrt{\left(\chi^2 / df - 1\right) / (n-1)}, \quad (5)$$

where χ^2 is the "normal" test statistic of the restricted vs. the unrestricted model. RMSEA(2) tests the restrictions of the one factor model. Values below 0.05 are considered as non-rejections. For the pooled sample and all sectors this test does not reject the one factor model. For sectors 9 and 10 the standard χ^2 test had to be used, since the RMSEA(2) statistic is not defined, but the model is also not rejected here. More formally, given that our covariance matrix has $K(K+1)/2$ elements and there are

$2K$ parameters to be estimated, we have $K(K-3)/2$ overidentifying restrictions. Our tests imply that those restrictions are never rejected for the one factor model.

Table 3. Factor loadings in the one factor model, pooled and across sectors.

Logged variables	Pooled	1	3	5	6	7	8	9	10
FCIT	0.6260	0.1961	0.9484	0.8944	0.4612	0.3802	0.4961	0.4597	0.2544
BCIT	0.1141	0.1599	0.1405	0.0874	0.1541	0.153	0.1811	0.2298	0.782
DCST	0.1257	0.3164	0.1634	0.0416	0.2319	0.1544	0.1719	0.4327	-0.0896
OPPOSITION	0.1601	0.1149	0.2112	0.0825	0.161	0.3191	0.2562	0.0946	0.1226
Observations	12,387	1,871	599	2,417	3,324	947	1,499	188	404
RMSEA(2)	0.0168	0.0073	0.0306	0.0402	0.0468	0.0377	0.0194	-	-
$\chi^2(2)$ p-value	-	-	-	-	-	-	-	0.43 (0.81)	1.77 (0.41)

Table 4. Percentage weights of indicators in the one factor model, pooled and across sectors.

Logged variables	Pooled	1	3	5	6	7	8	9	10
FCIT	72%	24%	95%	95%	51%	40%	51%	40%	12%
BCIT	8%	20%	1%	2%	14%	14%	14%	17%	87%
DCST	9%	42%	2%	1%	21%	14%	14%	37%	-4%
OPPOSITION	11%	14%	2%	2%	14%	32%	21%	7%	5%

3.3 Weights of different indicators

The weight vector for the contributing indicators can be calculated as:

$$\mathbf{w} = \mathbf{\Lambda}^{-1}\boldsymbol{\lambda}/\boldsymbol{\iota}'\mathbf{\Lambda}^{-1}\boldsymbol{\lambda}, \quad (6)$$

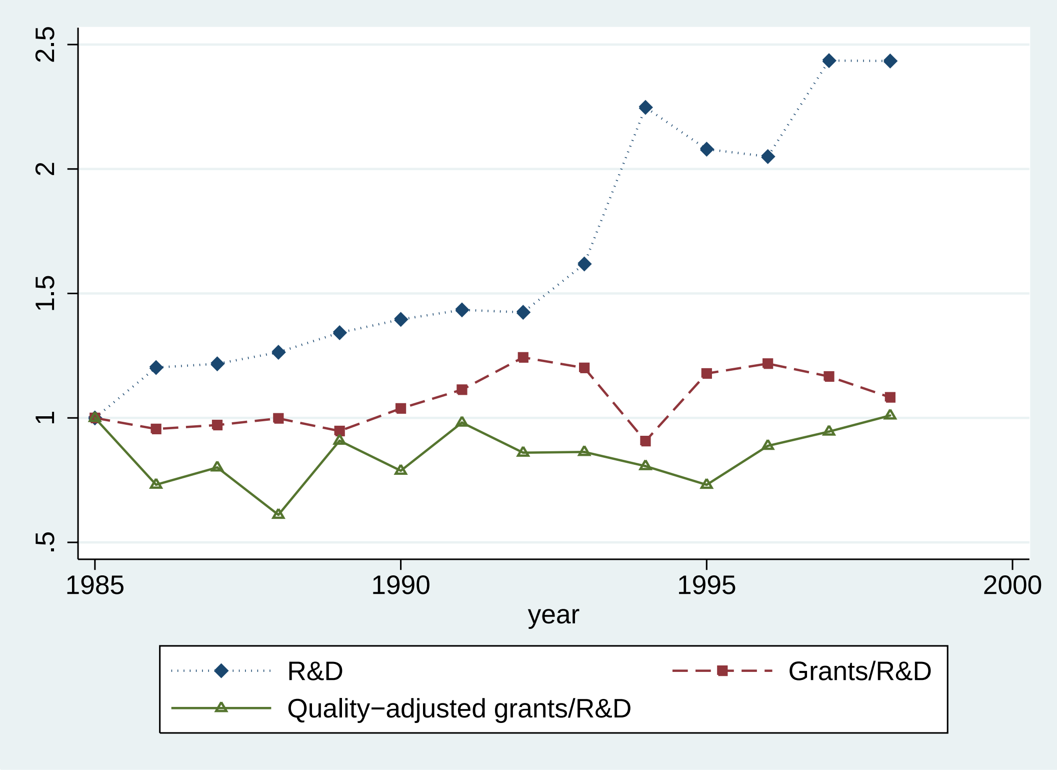
where $\boldsymbol{\iota}$ is a unit vector. The weights are thus expressed as their contribution as a share of all contributing indicators. Table 4 shows the calculated weights. For the pooled sample, *FCIT* has the highest weight or 72 % and opposition has the second largest. *FCIT* has the highest weight on the index in all sectors except “low- and medium tech manufacturing sectors” and “Research within science, engineering, and medicine”.

Intuitively, we would think that *FCIT* and *OPPOSITION* would be best correlated with value, and the literature seems to confirm this see e.g. (Harhoff et al., 2003). This stands in contrast to the results of Lanjouw and Schankerman (2004). Instead of our *OPPOSITION* they use the *CLAIMS* indicator. *CLAIMS* get their highest weights for 7 of 8 technologies. A major difference between the two studies is that we use EPO data while Lanjouw and Schankerman (2004) uses USPTO data. It has been shown that US patents tend to cite many more patents than European ones (Michel and Bettels, 2001). Therefore, while US forward citations may be indicative of value and prior knowledge (Jaffe et al., 2000) they are more noisy. It seems likely that the forward citations reported here are more indicative of quality, which could explain their higher weight in the indices.

3.4 Development of quality over time

Figure 2-Figure 10 show the development of R&D, grants to R&D ratios and estimated quality-adjusted grants to R&D ratios in our sectors. Figure 2 reveals that R&D in Sweden has been rising 2.5 times the level of 1985. Patenting has also risen by roughly the same proportion, making the ratio stay more or less constant. Quality-adjusted granted patents seemed to have a shaky development through the period up and until 1995, after which quality has picked up to reach the levels of 1985 again by 1998.

Figure 2. Pooled sample, R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.



For low- and medium tech manufacturing industries (Figure 3), patenting productivity in terms of number of patents produced exceeds that of R&D. R&D levels are roughly constant throughout the period, but patenting and, especially its quality has risen dramatically. This seems to corroborate earlier findings that firms with low R&D levels have generally higher productivity in terms of patenting. R&D-intensive industries often conduct more process-oriented research which is not always patentable.

Chemical industries (except pharmaceuticals) have had quite an erratic pattern. While R&D levels stay on roughly the same level, patent grants and especially quality displays hikes in 1988 and 1997. There are substantial drops in quality from 1990 to 1991 and 1997 to 1998. Machinery and equipment n.e.c. a quite even development. R&D levels seem to be slowly rising throughout the period to a level roughly double that of the 1985 level. Patenting levels are roughly constant at 1 or slightly lower as a share of R&D. The same goes for quality, with exception for a strong peak in 1991, which seems to be indicative of a 'technological hit'.[8] In electrical, electronics and precision equipment we find traces of the Swedish ICT boom: R&D levels have risen 4-5 times its 1985 level. At the same time patenting has also exploded, so that the patenting to R&D levels remain roughly on par. Quality levels follow patenting levels very closely.

[8] We plan to investigate this phenomenon more closely.

Figure 3. Low- and Medium-technology-intensive manufacturing sectors. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

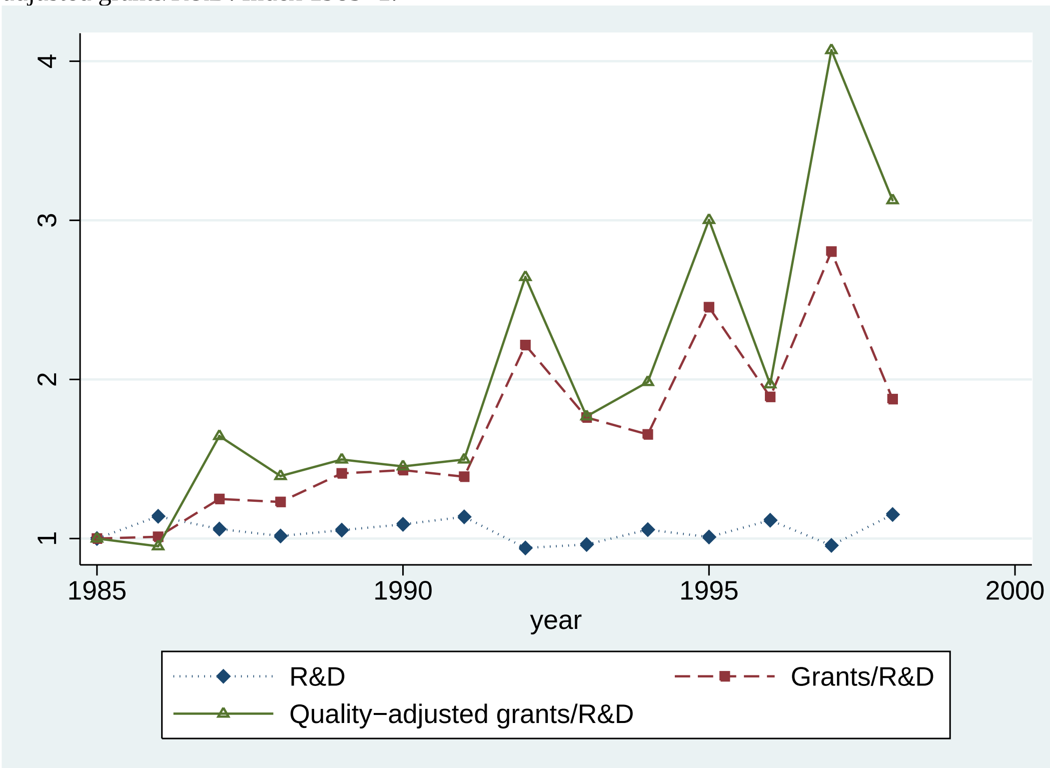


Figure 4. Chemical products. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

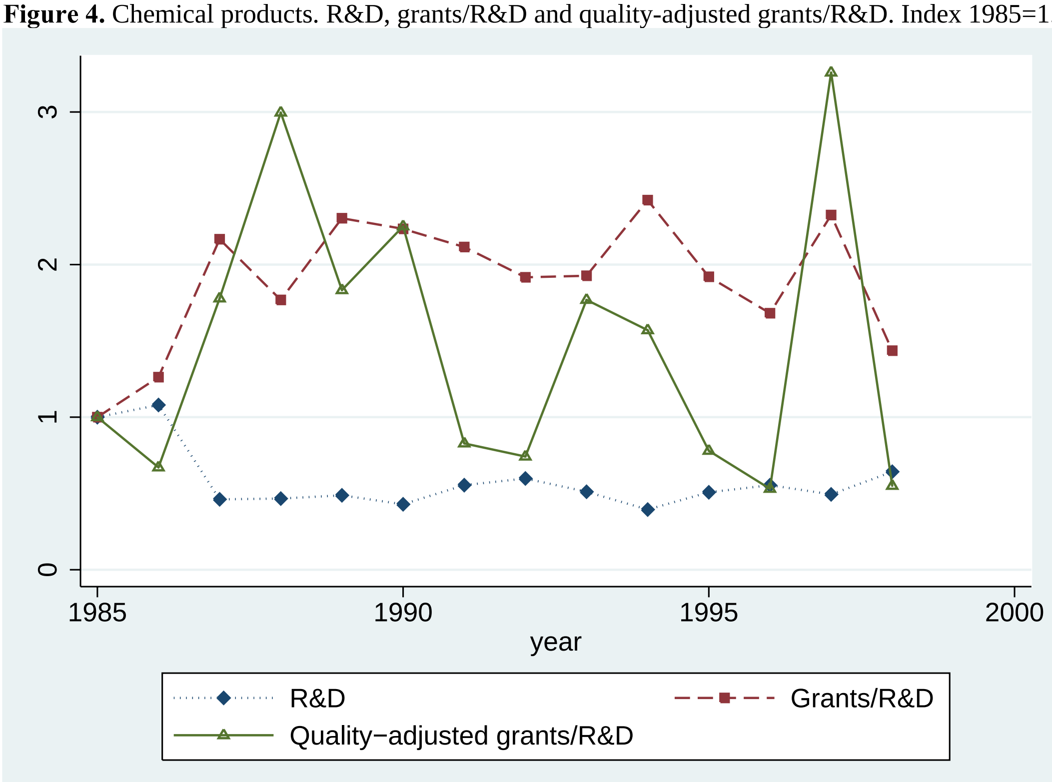


Figure 5. Machinery and equipment n.e.c.. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

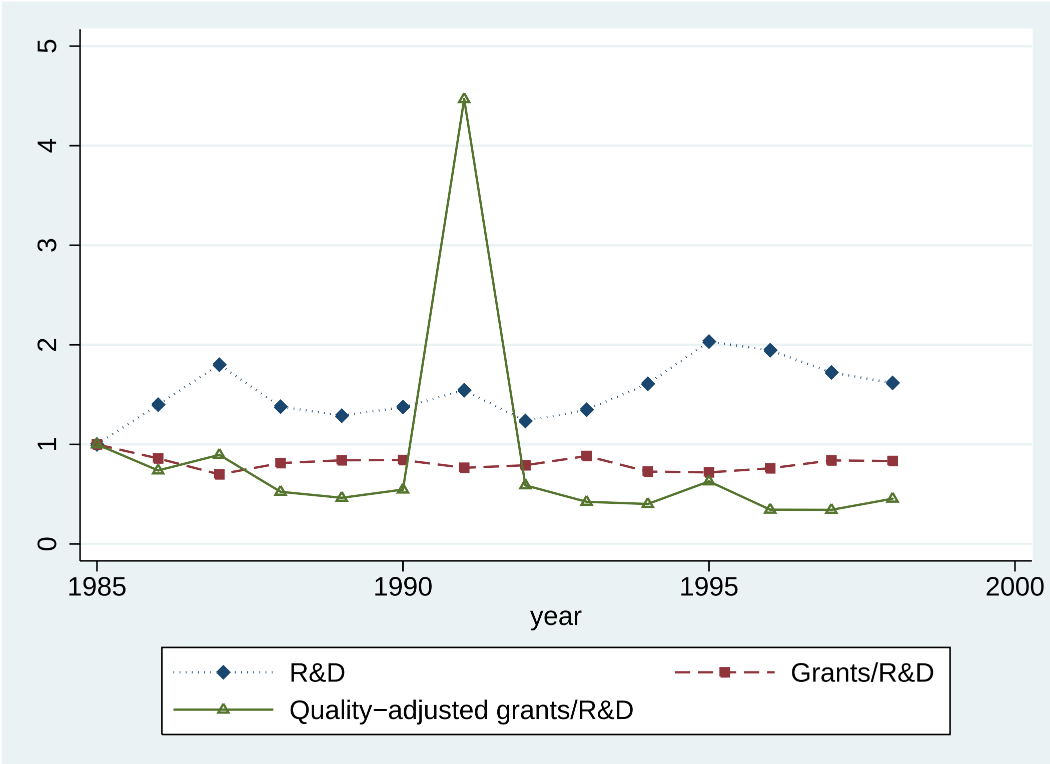
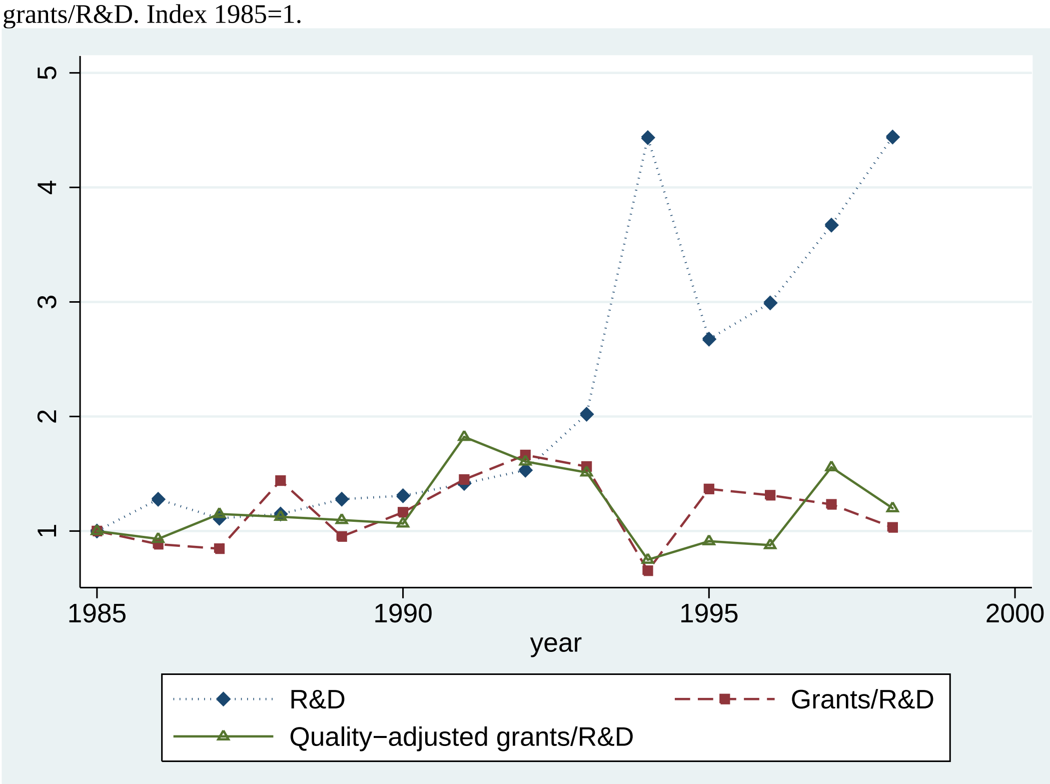
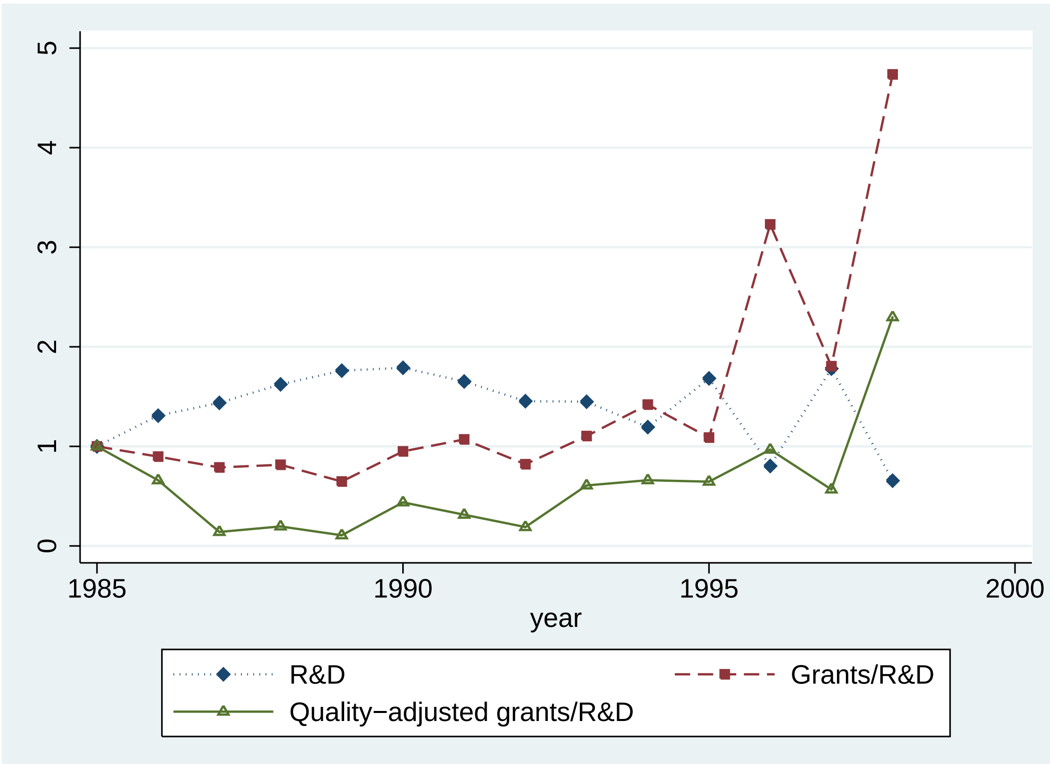


Figure 6. Electrical, electronics and precision equipment. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.



In transport vehicles and equipment, a second major Swedish production area, R&D levels rise somewhat from 1985 to 1990, with a secular and somewhat erratic falling trend from 1990 to 1998. Patenting rises dramatically from 1995 to 1998, but quality seems to be lagging behind.

Figure 7. Transport vehicles and equipment. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.



Low- and medium tech services display what seems like highly disordered data. R&D levels seem to have been rising quite a bit to about 2.5 times its 1985 levels. The grant to R&D and quality to R&D ratios have highly fluctuating developments from half its 1985 levels to twice its 1985 level. Service communications include telecommunications services, and here we find a second sign of the Swedish ICT boom. R&D levels have been rising firmly to more than 80 times its 1985 level. At the same time patenting and associated quality has remained stable.

Even more extreme are developments in the sector R&D in science, engineering and medicine. R&D levels were very low in the mid 80's before rising rapidly. From 1988 to 1990 the rise was about 500 times and levels were rising four times that level by 1998. Patenting and quality, on the other hand, remains the lowest of our investigated sectors. We think that the developments here may arise due to the development of business services and outsourcing of R&D from larger companies to smaller ones and start-up of R&D-intensive firms supportive of developments in major companies mainly in telecommunications.[9]

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[9] This would need further research to be corroborated.

Figure 8. Low- and Medium-technology-intensive service sectors. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

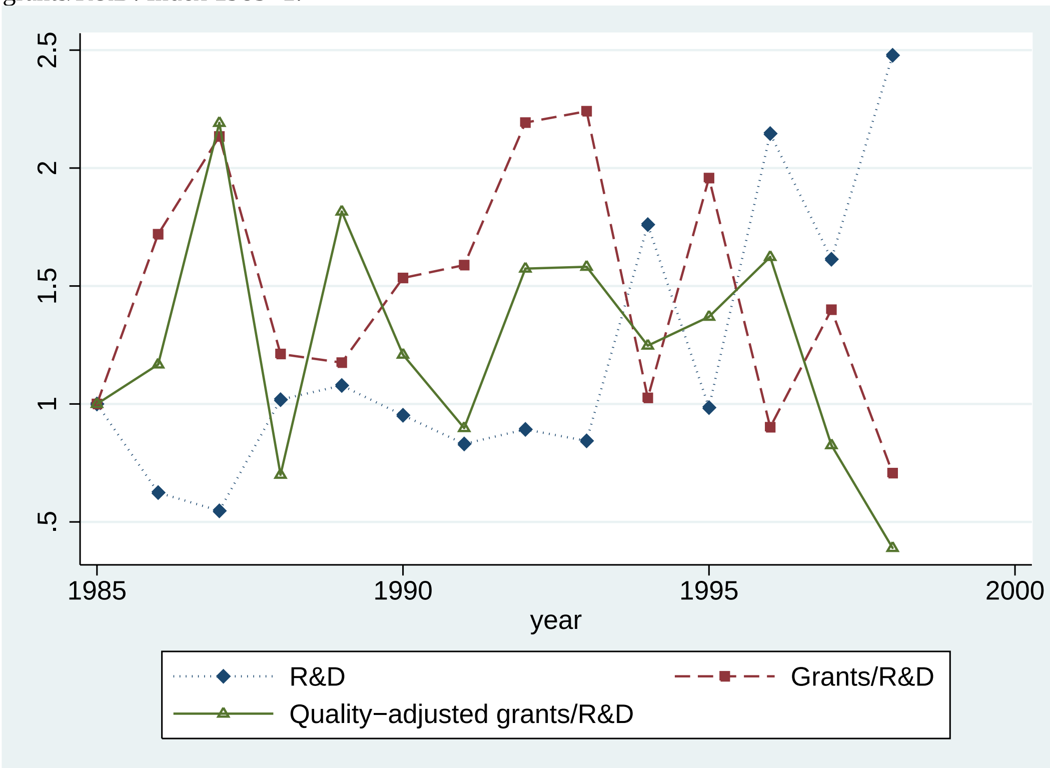


Figure 9. Service communication. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

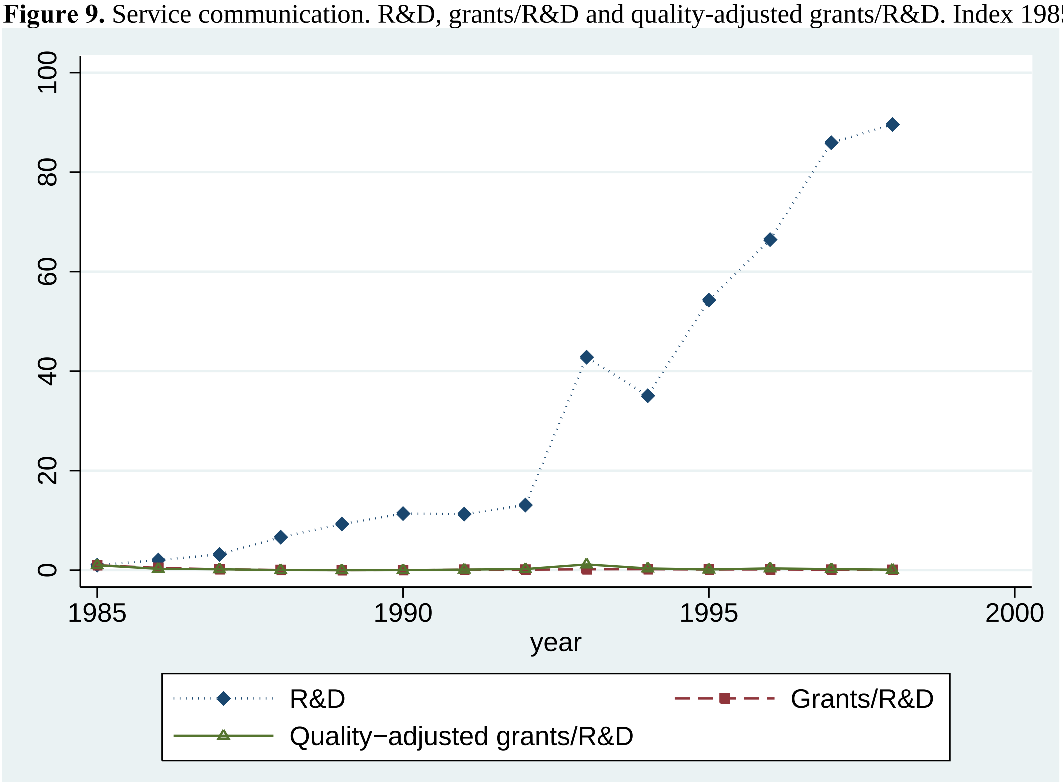
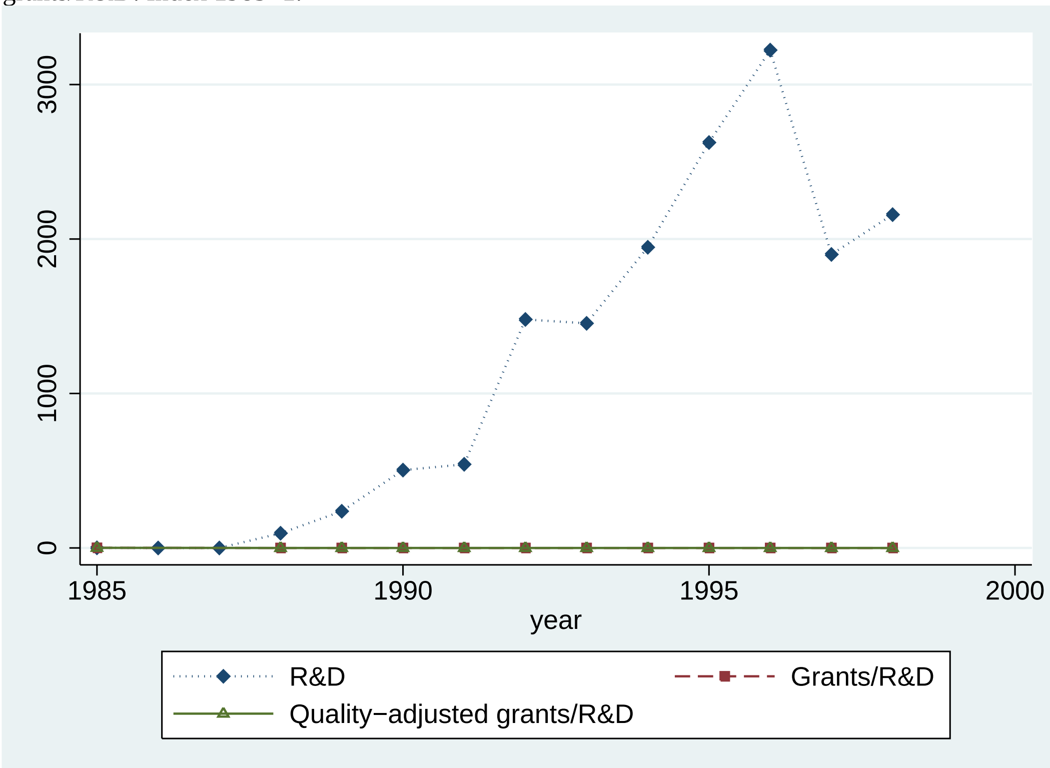


Figure 10. R&D in science, engineering, and medicine. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.



4 Conclusions

This paper relies on a new database covering the entire Swedish economy at the firm level 1985-2002, with data on R&D and patents with quality information used in this paper. The research questions are: 1) Whether patents/R&D ratios decline in the longer perspective, and 2) If patents become more or less valuable over time. The results are partly similar and partly different to the results based on US data (Lanjouw and Schankerman, 2004, Hall et al., 2005).

In contrast to the US, in the aggregate Swedish data indicate no trend in patenting patenting/R&D ratios over the period 1985-2002 on the aggregate level. During the same period Swedish R&D has been rising fast. On the sectoral level, low- and medium tech manufactures, chemicals and transport vehicles and equipment are industries where R&D levels remain fairly constant. Patenting productivity and associated quality seems to be fairly high, however, although quality seems to be lagging somewhat in low- and mediumtech industries and transport vehicles and equipment. The fastest rise in R&D in absolute terms is seen in Electrical, electronics and precision equipment. Interestingly, this development is not associated with a loss in patenting productivity nor in patenting quality. This suggests that developments here may be of a lasting character. Another striking finding are the strong developments of R&D in services, which comprise telecom services, and also in R&D in engineering, science and medicine. The first signals strong investments of telecommunications services industries in Sweden and the second may be a consequence of outsourcing and developments of supporting knowledge-intensive business services. Patenting remains low, which may reflect that these sectors have less patentable inventions.

A methodologically relevant result is that for our quality indicators, we find that forward citations plays a dominant role with opposition being second. This is in contrast to the quality indicators of Lanjouw and Schankerman (2004) who finds that number of claims is the most important quality indicator. We think this has to do with differences in use of patent data (USPTO vs. EPO).

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. Among the fractions, individuals were never counted as actual contributor to 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. For example: Patent A has five applicants, two Swedish individuals, two Swedish companies, one Danish individual and one Danish company. Exclusion of all individuals leaves us with three applicants to the patent, whereof Swedish firms are given 2/3 of the patent.

Appendix B: Sectoral division to CIRCLE10

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); “Service communication”

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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