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Swedish business research productivity – improvements against international trends

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Keywords: R&D, patenting, patent quality, sectors.

Swedish business research productivity – improvements against international trends[1]

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JEL classification: O10, O31, O52

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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 new light on research productivity, defined as the number of patents in relation to R&D, and quality-adjusted research productivity, which uses quality-adjusted patents instead. We have compiled an original database of nearly all Swedish firms, in manufacturing as well as in services, which has been matched to European Patent Office (EPO) patent data.

Research productivity has declined sharply in many countries and industries. 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 severe (Evenson, 1984, Evenson, 1993). The US has experienced a "patent explosion" since 1984 (Kortum and Lerner, 1999, Kortum and Lerner, 2003, Hall, 2005). The "explosion" in US patenting has been concentrated in the electrical, electronics, computing and scientific instruments industries. The patent explosion research does not explicitly address the development of research productivity, but it seems possible that the declining trend might have come to a halt. For the US it is clear that the declining trend had not stopped before 1993 (Lanjouw and Schankerman 2004). We study the period 1985-1998 for Sweden and explore two research questions. First, we investigate whether Sweden has a falling patent to R&D ratio in this period. Second, we explore whether quality-adjustment of patents changes the picture. We look first at the aggregate level and then divide the economy into ten sectors for these analyses.

2 Previous studies

Internationally falling patent to R&D ratios is a ‘stylized fact’ that has motivated attempts to sort out the reasons. Lanjouw and Schankerman (2004) present an interesting effort in this direction. They suggest four potential reasons for a decline in research productivity 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 research productivity 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.* Assuming decreasing returns, a decline in research productivity 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 technological exhaustion, 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

Lanjouw and Schankerman (2004) use the NBER 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.[3] Firms and patents are classified in one of seven technology areas: drugs, biotech, other health, chemicals, computers, electronics and mechanical. They assess to what extent increased patent quality can explain the fall in research productivity from 1980 to 1993 in the US. The answer depends partly on technology area. In drugs, quality improvement does not compensate for the fall in research productivity. In two sectors quality improvements are important for offsetting the decline in research productivity; 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 and quality-adjusted research productivity actually increases.

Attempts to measure patent quality has started fairly recently. For instance, Schmookler (1966) and Griliches (1984) assigned patents to industries and firms respectively, but did not assess patent quality. Patent quality indicators have been validated in two ways. Most 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 patent counts but found that citation-weighed counts were correlated. Harhoff et al. (1999) asked German patent

[3] Unfortunately, we are not given any information on whether this may bias R&D figures we adds to comparability problems with our data (see section 4.4).

holders to estimate a price at which they would have been willing to sell the patent right, and find a 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 a correlation between the stock market valuation of publicly traded firms and the "patent citations/patent"-ratio over the period 1976-1995.

3 Data material

Our base data consists of firm level data over the period 1985-2002, which is aggregated into sectors in this paper. The original dataset has been compiled by Statistics Sweden for a group of researchers at Lund University (Lundquist et al., 2005, Lundquist et al., 2006). The investigated period ends in 1998, although our database continues until 2002, because 'forward citations' – one of our quality indicators – take time to accumulate.

To this original database we have matched on patents from the European Patent Office (EPO) and added quality indicators. We obtained data on forward citations (*FCIT3*), backward citations (*BCIT*) and opposition (*OPPOSITION*), which shows whether the granted patent was opposed in court, from a DVD compiled by the OECD and documented in Webb et al. (2005).[4] Patents which are opposed are more likely to be valuable because they are viewed as threatening by competitors. *FCIT3* was calculated by us as all forward citations to a patent within three years from the publication date. The rationale is that the higher impact of a patent, the higher quality, at least for later technology development. Backward citations show if there is a lot of technological activity going in a field, but may also indicate that the technology is more derivative in nature. In

[4] The version we use was distributed in late 2006.

compiling citation indicators, Webb et al. (2005) considers patent equivalents. Two patents published by different patent offices are considered equivalent whenever they share *exactly* the same set of priority documents. In calculating forward citations, all forward citations to equivalents in the EPO and PCT-systems and backward citations are counted from such equivalents, after correcting for double-counting. Backward citations: number of prior patents cited in the application. Our fourth indicator, family size (*FAMSIZE*), was generously provided to us by Grid Thoma from PATSTAT data. It follows the methodology discussed and used in Graham and Harhoff (2006) and Hall et al. (2007). Here a *patent family* consists of those patents that have at least one priority document in common. Family size shows the number of patents protecting the same invention in different countries. More countries should be indicative of higher quality. We considered a patent Swedish if one of the inventors had a Swedish address. Statistics Sweden and a subcontractor (IRIS) helped us with the computerized matching. This work was complemented with manual work by us to choose the best match of names and addresses of applicants with firms in our database. We used fractional counting of applicants. Essentially this meant that we excluded what we considered as individuals listed as applicants and non-Swedish co-applicants.

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 1985-2002, 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 sector patterns, we apportioned the patent to the sector of the firm from the closest year at hand. This raised our match 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 match rate could differ over the time-period under study. Indeed, the match ratio was much higher in the latter part of the studied period ranging among applications from 74% in 1985 to 93% in 2002 (95% was obtained for some years).[5] We decided therefore to adjust the patent figures in each sector proportionally to the inverse of the matched ratio for individual years. This means that we removed the time trends imposed because of differing matching rates, which is crucial for the objective of this paper. Finally, we chose to concentrate our analysis to the 1985-1998 period due to lengthy grant procedures and to reduce truncation problems for forward citations.

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.[6] 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. Many more small firms were included in the base data from 1996 onwards.[7] This could theoretically have been a major problem for our investigation but 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.

[5] One reason could be that the database contains a much higher share of all existing firms since 1996, but it also seems likely that got better matching rates towards the end of the period because patent registers are continuously updated, whereas firm registers are not.

[6] 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.

[7] There were roughly 5,000 industrial firms in the database per year 1985-1995. From 1996 onwards, the number increased to roughly 35,000. For services, the number of firms increase from roughly 10,000 in 1995 to around 250,000 in 1996.

Our material covers 3,490 individual firms, or an average of 392 per year that conduct R&D and/or patenting. 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. However, only for a smaller fraction of these firms do they have R&D figures. Their research productivity (patents/R&D) figures may therefore be biased. Finally, we deflated R&D by a wage index of civil engineers to 1985 levels. [8] We are not given information on how this is done for the Hall, Jaffe and Trajtenberg database.

4 Sector division and quality-adjustment of patents

4.1 Sector division

We divided our material into rather broad sectoral groups. We chose to use a sectoral presentation, while also controlling for technological effects. This recognizes that technology development has sectoral as well as technological specificities (Cantner and Malerba, 2007). A reason for the use of broad groups is a change in sector classification in Sweden from SNI69 to SNI92.[9] Using rather aggregate sectors removes much of comparability problems over time. An additional advantage is that problems of arbitrary reclassifications of firms across sectors are reduced. Moreover, finer divisions that we tested yielded very little R&D and/or patenting for certain sectors, so they did not make much sense. 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 R&D intensive ones and to keep manufacturing sectors separate from service sectors. There are

[8] Source: Ljungberg (2006).
[9] These classifications closely correspond to ISIC rev 2 and ISIC rev 3 respectively.

seven sectors in manufacturing and three in services. Sector 1 consists of low- and medium-technology intensive manufacturing industries and primary sectors. Sectors 2 to 7 are high-technology intensive manufacturing sectors. Sector 8 consists of low- and medium-technology intensive service sectors, and Sectors 9-10 are high-technology intensive service sectors. A more detailed description of the content of these sectors is available from the authors upon request.

Table 1 provides summary statistics on granted patents and deflated R&D across our 10 sectors. The three highest figures of absolute average patenting 1985-1998 are found in increasing order in the groups “low- and medium-tech manufacturers”, “low- and medium-tech services” and in “electrical, electronics and precision equipment”. Low- and medium-tech groups get high patenting rates because we aggregate many different industries to these groups. Most R&D 1985-1998 is performed by “pharmaceutical related products”, “transport vehicles and equipment” and in “electrical, electronics and precision equipment”.

4.2 The quality of Swedish patents

As described above, we compose quality indices based on *FCIT3*, *BCIT*, *FAMSIZE* and *OPPOSITION*. The method to produce the indices is factor analysis which constructs a *common* factor explaining most of the joint variation in *FCIT3*, *BCIT*, *FAMSIZE* and *OPPOSITION*. The method basically follows Lanjouw and Schankerman (2004), Gambardella, et al. (2005) and Mariani and Romanelli (2006). The common factor is assumed to represent “quality”.

There are time trends in our indicators, which may not necessarily 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 regress the log of our indicators on yearly time dummies, and dummies representing the technologies patents belong to[10]:

(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.[11] 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.

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

<TABLE 1 ABOUT HERE>

The quality component is given by:

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

[10] There are 30 technology dummies based on the technology classification originally developed by Hinze at al. (1997).

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

Since we have logged our indicators, we took the antilog of the above calculated values to form our quality indices. Table 2 shows the correlation matrix of the residuals obtained from the quality indicators pooling all patent data.

<TABLE 2 ABOUT HERE>

The results of the one factor model for the pooled model and the individual sectors are presented in Table 3. The one factor model produced theoretically inconsistent, negative factor loadings for group 2 (Pulp, paper and paper products). For group 3 (Chemical products) and 5 (Machinery and equipment n.e.c.) Heywood solutions or boundary solutions were obtained. For those three cases the common factor is not meaningful and is not presented. For the remaining sectors, given a covariance matrix of $K(K+1)/2$ elements and $2K$ parameters to be estimated, we have $K(K-3)/2$ overidentifying restrictions. Normally a χ^2 test is done to test the one factor restricted model. However, this test is best suited to samples of 75-200 observations. For our larger samples, the χ^2 test has too strong power. Instead, the Root Mean Square Error Approximation test can be used for larger samples (Bollen and Long, 1993). It is written:

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

where χ^2 is the test described above. 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 1, 7, 9 and 10 the standard χ^2 test had to be used, since the RMSEA is not defined. Even here the more powerful χ^2 test does not reject the model. The tests thus never reject the restrictions for the one factor model.

<TABLE 3 ABOUT HERE>

<TABLE 4 ABOUT HERE>

4.3 Weights of different indicators

The weight vector for the contributing indicators are calculated as:

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

where $\boldsymbol{\iota}$ is a unit vector. The weights show each indicator's contribution as a share of all contributing indicators. Table 4 shows the calculated weights. For the pooled sample, *FCIT3* has the highest weight of 55% and *FAMSIZE* the second largest (18%). Moreover, *FCIT3* has the highest weight on the index in all sectors except pharmaceutical related products (*FAMSIZE*, 34%) and transport vehicles and equipment (*OPPOSITION*, 67%).

Judging from the literature (cf. Harhoff et al., 2003), *FCIT3* and *OPPOSITION* would probably be best correlated with value. In Lanjouw and Schankerman (2004). *CLAIMS*, the number of novel features, is used instead of *OPPOSITION*. *CLAIMS* get their highest weights for 7 of 8 technologies. Two differences may account for the differing results with respect to the importance of different indicators of quality. First, the four indicators of quality differ from the two investigations. Secondly, while we use EPO data Lanjouw and Schankerman (2004) uses data from the USPTO. Evidence shows 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 they are more noisy (Jaffe et al., 2000). It seems likely that the forward citations reported here are more indicative of quality, which could explain their higher weight in the indices.

4.4 Development of quality over time

Figure to Figure 8 show the development of R&D, grants to R&D ratios and estimated quality-adjusted grants to R&D ratios pooled and in our sectors. For the sectors "pulp, paper and paper products", "chemical products" and "machinery and equipment", it was not possible to obtain quality indices with factor analyses. Those sectors are therefore omitted in the following figures. Descriptive data on patents and R&D, also for those sectors, are given in Table 1.

<FIGURE 1 ABOUT HERE>

Figure 1 reveals that total Swedish R&D rose 2½ times between 1985 and 1998. Patenting rose somewhat faster, resulting in a modest overall increase in research productivity over time. Quality-adjusted research productivity shows an even more accentuated rise of patents to R&D over the entire period, but the development differs among sectors. Quality-adjusted patents to R&D ratio had a less favorable development in the beginning of the period (1985-1989). Then there was a period (1989-1995) where quality improves and roughly follows patenting. Thereafter (1996-1998), quality of patents improved substantially and above patenting levels.

Our data shows that Swedish firms produce an average of 0.19 patents per million R&D in 1985 and a value of 0.21 for 1998.[12] Data from Lanjouw and Schankerman (2004) indicate a median value ranging from 0.27 (drugs) to 0.59 (other health). In Hall et al. (2005, Figure 1) we find a series showing the patent/R&D-ratio dropping from 1975 year's average ratio of more than 0.6 patents per million R&D dollars to around 0.3 in 1987 and in 1993. Unfortunately, these data are not easily comparable to ours: our R&D comprises all R&D performed, while their data only includes a small subset of the patenting firms for which they have R&D data; we have adjusted our patent and R&D values to comprise the whole economy; we have used fractional patent counting, excluding individuals, foreign companies and small companies owned by individuals. It is not easy to assess in which direction any eventual biases arises. Nevertheless, we can be quite sure that *developments* are favorable for Sweden, when patents are counted by their sheer numbers and by adjusting for quality.

[12] Using exchange rate data gives us the values 0.21 and 0.23 respectively instead. We used PPP-figures and exchange rate data for Sweden from the Penn World Tables 6.1 (Heston et al., 2002).

<FIGURE 2 ABOUT HERE>

For “low- and medium tech manufacturing industries” (Figure 2Figure 2), research productivity has increased substantially over time. This sector therefore contributes to the overall somewhat increasing research productivity on the aggregate level. R&D levels are roughly constant throughout the period, but patenting and, especially its quality has risen dramatically. This is in line with earlier findings that firms with low R&D levels have generally higher productivity in terms of patenting (Bound, 1984). R&D-intensive industries often conduct more process-oriented research which is not always patentable.

<FIGURE 3 ABOUT HERE>

The sector “pharmaceutical related products” (Figure 3) has increased its R&D spending to about 3.5 times its 1985 level. Patenting to R&D remains fairly constant. Quality shows more variation, but no marked trend.

<FIGURE 4 ABOUT HERE>

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 (Figure 4Figure 4). At the same time patenting has also increased dramatically, so that research productivity has increased slightly. Quality levels follow patenting levels very closely except for 1997. Closer examination shows that a handful patents, most likely highly valuable one, are responsible for this impact on the index. We can thus see a similar patent explosion in this sector as in the US.

<FIGURE 5 ABOUT HERE>

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 (Figure 5Figure 5). Patenting rises dramatically from 1995 to 1998, but although quality also improves it lags behind.

<FIGURE 6 ABOUT HERE>

“Low- and medium tech services” display quite uneven development. R&D levels rose to about 2½ times its 1985 levels (Figure 6Figure 6). Research productivity is quite a lot higher than the 1985 level through most of the period, but ends at the same level. Quality is dramatically higher than patenting levels throughout the period, just as in low- and medium-tech manufacturing, but also ends at the 1985 level.

<FIGURE 7 ABOUT HERE>

“Service communications” include telecommunications services, and here we find a second sign of rising R&D in the wake of the ICT boom (Figure 7Figure 7). R&D has been rising firmly to more than 80 times (left axis) its 1985 levels in 1998. At the same time patenting and quality-adjusted patenting (right axis) to R&D has declined sharply.

<FIGURE 8 ABOUT HERE>

Even more extreme are developments in the sector “R&D in science, engineering and medicine” (Figure 8). R&D levels were very low in the mid 80’s before rising rapidly. From 1988 to 1990 the level had risen about 500 times and levels rose an additional four times that level by 1998.[13] Patenting and quality, on the other hand, remains the lowest of our investigated sectors. We may speculate that developments here may be a consequence of strong business services development in the sector, of 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. If larger firms retain the ownership of patents produced, that would also explain the low patent levels seen for this sector.[14]

[13] Our data shows that the 1985 level was fairly high but dropped sharply. No R&D for 1986-1987 was observed. Therefore we excluded the first three years to be able to visualize trends over time.
[14] This would need further research to be corroborated.

5 Conclusions

This paper relies on a new database covering the entire Swedish economy at the firm level. Our analysis in this paper covers the period 1985-1998 with data on R&D complemented with matched patents with associated quality information. Our research questions are: 1) Do patents/R&D ratios decline in the longer perspective? 2) Do patents become more or less valuable over time? The results are partly similar and partly different to results based on US data (Lanjouw and Schankerman, 2004, Hall et al., 2005).

In contrast to US data, our Swedish data actually displays a slightly increasing trend in patenting/R&D ratios over the period 1985-1998 on the aggregate level. During the same period Swedish R&D rose fast as did patenting. This means that the notion of a more or less constantly falling patent to R&D ratio for the US and Europe does not apply to the Swedish case (Evenson, 1993). That our results differ from the stylized fact may reflect that the present study covers a longer time period. The Swedish development is essentially one of favorable development in terms of research productivity and quality-adjusted research productivity across the board as seen over the entire time period. Less favorable developments can only be observed in sectors with very little patenting at the outset. Even though there are comparability problems between our data and earlier efforts since our data is more encompassing, we are confident that *developments* are favorable for Sweden, when patents are counted by their sheer numbers. When accounting for quality, quality-adjusted patent indices increase faster than just patent numbers. There is thus no evidence of declining research productivity, but in fact it seems to be improving.

A methodologically relevant result is that for our quality indicators, we find that forward citations play 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 types of patent data (USPTO vs. EPO).

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Tables

Table 1. Descriptive data on R&D and patenting in our 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) 1985-1998				Sum R&D (deflated), billion SEK 1985-1998			
			Min	Avg	Max	SD	Min	Avg	Max	SD
1	L&M, M	See Appendix B	40.1	80.5	128.5	27.0	1.4	2.1	3.0	0.5
2	H, M	Pulp, paper and paper products	9.0	24.2	42.5	10.7	0.5	0.9	1.4	0.3
3	H, M	Chemical products (excl pharma)	16.5	21.5	25.2	2.8	0.4	0.7	1.0	0.2
4	H, M	Pharmaceutical related products	13.0	26.8	63.5	15.1	1.4	4.2	9.7	2.8
5	H, M	Machinery and equipment n.e.c.	72.4	101	128.0	17.0	1.4	3.3	5.1	1.1
6	H, M	Electrical, electronics and precision equipment	47.2	139.1	261.0	78.0	3.3	11.8	28.8	8.7
7	H, M	Transport vehicles and equipment	20.3	41.1	78.0	18.6	3.6	7.4	12.1	2.4
8	L&M, S	See Appendix B	58.3	106.1	157.3	31.9	0.3	1.0	2.5	0.6
9	H, S	Service communication	0.0	13.4	36.0	13.6	0.0	1.1	3.6	1.3
10	H, S	R&D in science, engineering, and medicine	17.5	28.7	43.8	8.2	0.0	1.3	3.7	1.3

Table 2. Correlation matrix of residuals from quality indicators.

	FCIT3	*BCIT*	*FAMSIZE*	*OPPOSITION*
FCIT3	1			
BCIT	0.0729	1		
FAMSIZE	0.1030	0.0399	1	
OPPOSITION	0.0867	0.0030	0.0432	1

Table 3. Factor loadings in the one factor model, pooled and across sectors 1985-1998.

Logged variables	Pooled	Low- and medium-tech manufact.	Pharma. related products	Electrical, electronics and precision equipment	Transport vehicles and equipment	Low- and medium-tech services	Service communication	R&D in science, engineering, and medicine
FCIT3	0.500	0.306	0.362	0.347	0.225	0.348	0.696	0.428
BCIT	0.146	0.195	0.426	0.190	0.032	0.118	0.142	0.390
FAMSIZE	0.214	0.164	0.444	0.328	0.245	0.324	0.238	0.390
OPPOSITION	0.169	0.144	0.120	0.088	0.643	0.283	0.074	0.185
Observations	8,237	1,139	376	1,966	582	1,494	184	404
RMSEA(2)	0.015	-	0.044	0.036	-	0.028	-	-
χ^2(2) p-value	-	1.50 (0.47)	-	-	1.07 (0.59)	-	0.43 (0.81)	0.41 (0.81)

Table 4. Percentage weights of indicators in the one factor model, pooled and across sectors. Percentages may not always sum to 100% due to rounding.

Logged variables	Pooled	Low- and medium-tech manufact.	Pharma. related products	Electrical, electronics and precision equipment	Transport vehicles and equipment	Low- and medium-tech services	Service communication	R&D in science, engineering, and medicine
FCIT3	55%	39%	26%	38%	15%	33%	74%	32%
BCIT	12%	24%	32%	19%	2%	10%	8%	28%
FAMSIZE	18%	20%	34%	35%	16%	31%	14%	28%
OPPOSITION	14%	17%	8%	8%	67%	26%	4%	12%

Figures

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

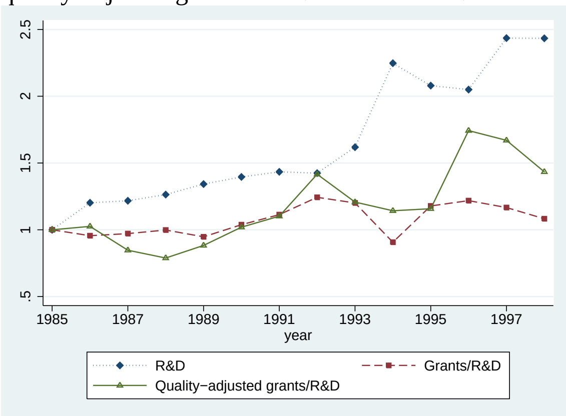


Figure 2. Low- and Medium-technology-intensive manufacturing sectors. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

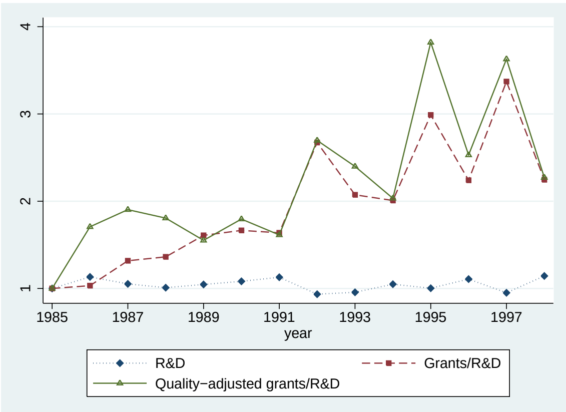


Figure 3. Pharmaceutical related products. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

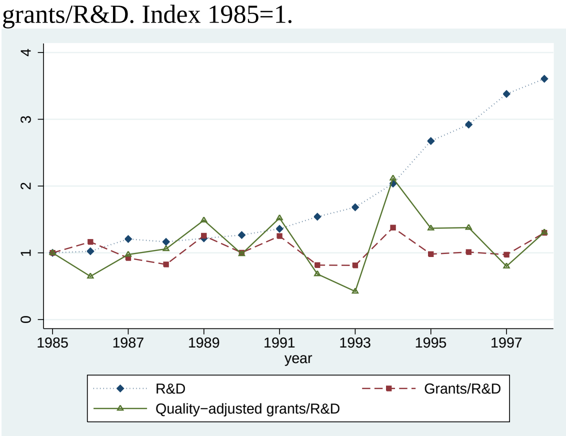


Figure 4. Electrical, electronics and precision equipment. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

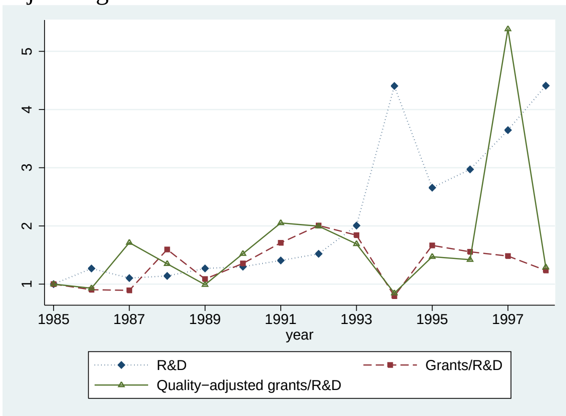


Figure 5. Transport vehicles and equipment. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

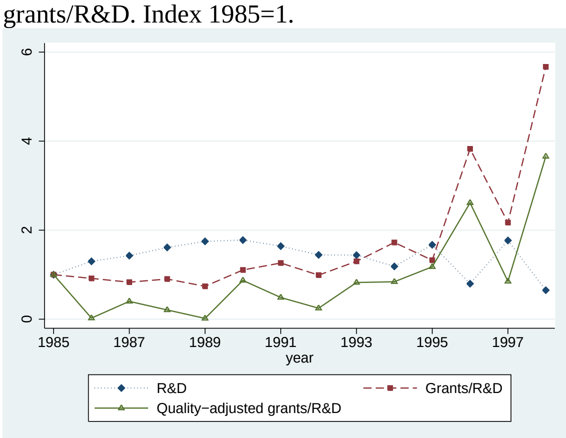


Figure 6. Low- and Medium-technology-intensive service sectors. R&D, grants/R&D and quality-adjusted grants/R&D. Index 1985=1.

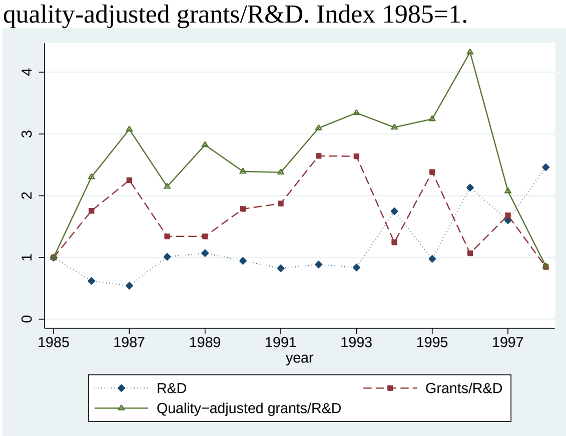


Figure 7. Service communication. R&D (left axis), grants/R&D and quality-adjusted grants/R&D (right axis). Index 1985=1.

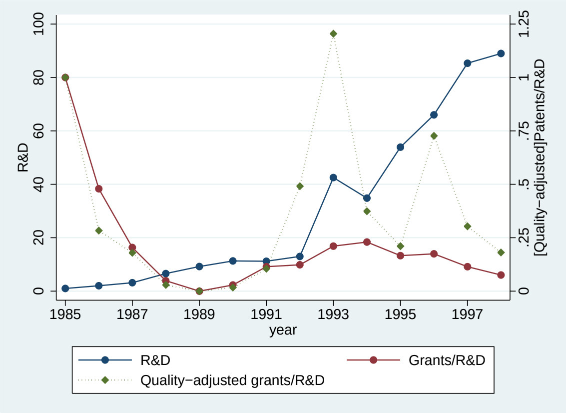
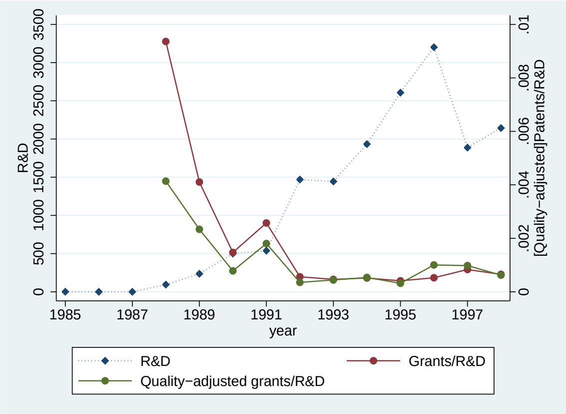


Figure 8. R&D in science, engineering, and medicine. R&D (left axis), grants/R&D and quality-adjusted grants/R&D (right axis). Index 1985=1.



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