The Importance of Accessibility to R&D on Patent Production in Swedish Municipalities

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Abstract

The main purpose in this paper is to study to what extent accessibility to R&D can explain patent production. Therefore a knowledge production function is estimated both on aggregated level and for different industrial sectors. The output of the knowledge production is the number patent applications in Swedish municipalities from 1994 to 1999. In order to account for the importance of proximity, the explanatory variables are expressed as accessibilities to university and company R&D. The total accessibility is then decomposed into local, intra-regional and inter-regional accessibility to R&D. The results indicate that high accessibility (local) to company R&D has the greatest effect on patent production. Local accessibility to university R&D has also a significant positive effect but the magnitude is smaller. There is also evidence that intra-regional accessibility to company R&D affects patent production positively.

Keywords: innovations, patents, R&D, knowledge production functions
JEL Codes

1. Introduction

The five largest municipalities in Sweden account for 20 % of Sweden's population also account for 28 % of Sweden's patent applications. Can this be explained by the high concentration of university and company R&D to these municipalities, or is it because of other factors? In order to get satisfactory explanations of questions like this, the paper starts with a discussion of the importance of proximity on knowledge flows and innovation systems.

Knowledge flows is a concept that covers different types of flows where knowledge is involved. In Johansson (2004) knowledge flows are divided into two main groups:

i) Transaction-based flows, i.e. the parties involved agree on a transaction of knowledge
ii) Knowledge spillovers, i.e. knowledge is an unintended side effect of ordinary activities

Knowledge spillovers can in turn be mediated by market mechanisms or be a pure externality. A pure externality in this context is for example when companies observe and copy techniques from each other. The importance of geographical proximity on knowledge diffusion has been revealed in several studies. Jaffe (1989), Jaffe et al. (1993), Feldman (1994) and Audretsch & Feldman (1996) stress that R&D and other knowledge spillovers not only generate externalities, but also that they tend to be geographically bounded within the region where the new economic knowledge was created. Closeness between agents and other members in the regional innovation system is more likely to offer greater opportunities to interact face to face, which will develop the potential of the innovation system. The theoretical explanation is that a great deal of new economic knowledge relevant in different innovation processes is hard to codify and is therefore not perfectly available. Thus, in most cases, face to face contacts are necessary for transferring tacit (complex) knowledge. Bottazzi & Peri (2003) think of the imperfectly codified part of the knowledge as a "local public good" as it benefits scientists within the region or its neighbourhoods but it diminish as contacts and interactions decrease. Breschi & Lissoni (2001a,b) are on the other hand critical to the view that tacit knowledge are freely available locally. They argue that sharing of tacit knowledge not only require spatial proximity but also "social" proximity, i.e. elements like mutual trust.

There are several possible ways to measure geographical proximity. Jaffe (1989) introduces a geographical coincidence index between public and private sector research. Autant-Bernard (2001), Acs et al. (2002) and Bottazzi & Peri (2003) compare different geographical levels, by introducing external research stock occurring on the periphery of a particular area. A geographical area's innovation capacity is therefore related to internal R&D effort but also to spillovers flowing from research activities in neighbouring areas. Botazzi & Peri (2003) also use distance (in kilometres) between different regions when investigating the importance of geographical proximity on knowledge spillovers. Karlsson & Manduchi (2001) have proposed an accessibility concept in order to incorporate geographical proximity. The accessibility measure is based on Weibull (1976) and is constructed according to two main principles. Firstly, the size of attractiveness in a destination has a positive effect on the propensity to travel. Secondly, the time distance to a destination affects the propensity to travel negatively. Many years of research has shown that the functional form derived by Weibull (1976) is superior other measures explaining peoples' travel in space. One of the most appealing features of the accessibility concept is that it contains actual time distances between regions/municipalities. Beckman (2000) is also of the opinion that travel time is the most appropriate measure of distance when dealing with knowledge networks. Beside simulation of changes in the R&D stock, it is also possible to study effects of simulated improvements in the infrastructure of the transportation system. Andersson & Karlsson (2003) demonstrates how the accessibility concept can be used as a measure of proximity in studies of knowledge spillovers and innovations. In Andersson et al. (2003) the accessibility concept is applied as a measure of proximity in regional innovation systems.

There has been a discussion in the literature about relevant measures of the output of innovation systems. Jaffe et al. (1993) have used a "paper trail" of patent citations to track the direction and intensity of spillovers. Peri (2002) argues that this approach only can identify intensity and direction of knowledge flows and not R&D externalities. Moreover, citations do not capture non-codified knowledge flows and embodied knowledge flows, which could be important sources of localized spillovers, as Saxenian (1991) and Audretsch & Feldman (1996) argue.

The two most common and frequently used innovation indicators are R&D efforts (measured by expenditures on R&D or persons carrying out R&D) and the number of patented inventions. According to Kleinknecht et al. (2002) these two measures have more weaknesses than it is often assumed. One obvious disadvantage is that R&D is an input of the innovation process and says very little about the output. Patents may be good indicators of the technology creation, even if not all new innovations are patented, but they do not measure the economic value of the technologies (Hall et al. 2001). In contrast to proxies of innovation activities such as R&D efforts or patents, literature-based innovation output measures provide a direct indicator of innovation (Acs et al. 2002 and Kleinknecht et al. 2002). Screening the new product announcements in trade and technical journals generates literature-based innovation output indicators. The advantage of these indicators is that they document the actual commercialisation of technical ideas.

The final output of an innovation system is not patent applications or granted patents. Together with R&D efforts they are costs in the innovation process. Benefits from the process are measured when patents are commercialised and contributes to economic growth, but this is beyond the scope of this paper.

The purpose with this study is to explore the importance of accessibility to R&D, on the Swedish regional innovation systems. By estimating knowledge production functions for the innovation systems, both on aggregated level and for different industrial sectors, it is possible to answer questions like:

- To what extent can accessibility to university R&D and company R&D explain patent production in Swedish municipalities?
- To what extent does the surrounding economic activity affect the municipalities' patent production? Are there structural differences between different types of municipalities (small, big etc.)?

2. Model

The conceptual framework for analyzing geographic spillovers is based on the knowledge production function of Griliches (1979). In order to examine the influence of knowledge flows on the output of regional innovation systems, it is possible to use the number of patents in each region as an endogenous variable, regressed against the R&D effort from companies and universities (see Jaffe 1989, Feldman & Florida 1994, among others). In this paper, the accessibility to R&D is used instead of R&D stock. The accessibility concept is shown in detail in Andersson et al. (2003) and the concept's major features are for expository purposes repeated here. In this paper, however, the research unit is municipalities instead of regions. Then the number of observations increases and enables a more developed model. It is also possible to estimate effects that are very local.

The accessibility of municipality *i* to it self and to *n-1* surrounding municipalities is defined as the sum of its internal accessibility to a given opportunity *D* and its accessibility to the same opportunity in other municipalities,

$$A_i^D = D_1 f(c_{i1}) + \ldots + D_i f(c_{ii}) + \ldots + D_n f(c_{in}) \tag{2.1}$$

where A_i^D is the total accessibility of municipality *i*. D_i is a measure of an opportunity (face-to-face contact), which can be an opportunity such as universities, R&D institutes, suppliers, customers etc. *f(c)* is the distance decay function that determines how the accessibility value is related to the cost of reaching the opportunity. A common approximation of *f(c)* is to apply an exponential function, and then it takes the following form,

$$f(c_{ij}) = \exp\{-\lambda t_{ij}\} \tag{2.2}$$

where t_{ij} is the time distance between municipality *i* and *j,* and λ is a time sensitivity parameter. The value of λ depends on if the interaction is intra-municipal, inter-municipal within the region, or inter-municipal outside the region. Equation (2.1) and (2.2) together generate

$$A_i^D = \sum_{j=1}^{n} D_j \exp\{-\lambda t_{ij}\} \tag{2.3}$$

It is apparent that the accessibility value may improve in two ways, either by an increase in the size of the opportunity, D_j, or by a reduction in the time distance between municipality *i* and *j*. If the total accessibility to a specific opportunity is decomposed into intra-municipal, inter-municipal within the region, and inter-municipal outside the region, then (2.3) becomes

$$A_i^D = A_{iL}^D + A_{iR}^D + A_{iXR}^D \tag{2.4}$$

where $A_{iL}^D = D_i \exp\{-\lambda_1 t_{ii}\}$, intra-municipal (local) accessibility

$A_{iR}^D = \sum_{r \in I,\ r \neq i} D_r \exp\{-\lambda_2 t_{ir}\}$, inter-municipal accessibility within the region

$$A_{iXR}^{D} = \sum_{k \notin I} D_k \exp\{-\lambda_3 t_{ik}\}$$, inter-municipal accessibility outside the region

r defines municipalities within the own region *I*, and *k* defines municipalities in other regions. λ_1 is set to 0.02, λ_2 to 0.1 and λ_3 to 0.05. Johansson, Klaesson & Olsson (2003) estimated these values by using data on commuting flows within and between Swedish municipalities in 1990 and 1998.

When the accessibility variables are calculated they can be entered in a Cobb-Douglas type of knowledge production function

$$\ln K_i = \alpha + \sum_{D=1}^{k} \beta_D \ln A_i^D + \varepsilon_i \tag{2.5}$$

where K_i is the knowledge output in municipality *i*. β_D is the elasticity for accessibility A_i^D, where *D* denotes the specific opportunities. ε_i is a normally distributed error term. However, if data consists of a large number of zeroes, then equation (2.5) is not applicable. This is the case with local accessibility to R&D and therefore (2.5) is replaced by a straight forward additive linear model.

$$K_i = a + \sum_{D=1}^{k} b_D A_i^D + \varepsilon_i \tag{2.6}$$

In this paper the number of patent applications is used as output measure (K_i). Local, intra-regional and inter-regional accessibility to university and company R&D are the explanatory variables. In addition to two dummy variables, measuring the size of the population in the municipalities, are included in the model. These variables enable a comparison between municipalities with a large (D_1), medium sized (D_2) and a small population. Thus, to check if accessibility to university R&D and company R&D explain patent production in Swedish municipalities, the following model is estimated:

$$Pat_i = a + b_1 A_{iL}^{uR\&D} + b_2 A_{iR}^{uR\&D} + b_3 A_{iXR}^{uR\&D} + b_4 A_{iL}^{cR\&D} + b_5 A_{iR}^{cR\&D} + b_6 A_{iXR}^{cR\&D} + b_7 D_1 + b_8 D_2 + \varepsilon_i \tag{2.7}$$

3. Data and descriptive statistics

The data concerning the number of patent applications are taken from The European Patent Office. Statistics Sweden collects data on performed R&D in universities and companies and National Road Administration in Sweden is the data source when it comes to commuting time between and within Swedish municipalities.

- The number of patents is a yearly average during the period of 1994-1999 in the municipalities of Sweden.
- Accessibility to university R&D is computed using the stock of university R&D measured in man years during the period 1993/94-1999 for Swedish municipalities.
- Accessibility to company R&D is computed using the stock of company R&D measured in man years during the period 1993-1999 for Swedish municipalities.

Data of the commuting time between and within municipalities in 1990 and 1998 is used for calculating the accessibility variables. The descriptive statistics of the variables in equation 2.7 are presented in table 3.1. The variable "Large population" equals one if population is greater than 100 000 and "Medium population" equals one if population is between 50 and 100 000.

Table 3.1: Descriptive statistics

	N	# of zeroes	Minimum	Maximum	Median	Mean	Std. Deviation
No of patents	288	27	0.00	203.83	1.17	5.35	15.94
Access to univ R&D, municip	288	194	0.00	3012.26	0.00	52.53	320.82
Access to univ R&D, intra-reg	288	86	0.00	1990.38	1.73	114.91	300.98
Access to univ R&D, inter-reg	288	0	0.0005	1022.65	22.64	96.49	164.15
Access to comp R&D, municip	288	143	0.00	643.80	0.001	8.34	46.34
Access to comp R&D, intra-reg	288	61	0.00	383.32	0.641	19.47	50.91
Access to comp R&D, inter-reg	288	0	0.0001	168.15	7.39	13.89	19.34
Large pop	288	277	0.00	1.00	0.00	0.038	0.192
Medium pop	288	252	0.00	1.00	0.00	0.125	0.331

Note especially the large number of zeroes for some variables, which made a Cobb-Douglas production function inappropriate to use.

Table 3.2 shows the ten municipalities in Sweden with the highest patent production. Note that the concentration of patents, university and company R&D to the largest municipalities is higher than it is for population.

Table 3.2: Share of Sweden's patent production, population and R&D (rank)								
	Patents (1994-99)		Population (1999)		University R&D (man-year, 1993-99)		Company R&D (man-year 1993-99)	
Stockholm	13.2%	1	8.4%	1	19.1%	1	26.0%	1
Göteborg	6.8%	2	5.2%	2	17.1%	3	8.3%	3
Lund	4.9%	3	1.1%	12	13.3%	4	7.3%	5
Uppsala	4.1%	4	2.1%	4	18.5%	2	4.8%	6
Västerås	4.0%	5	1.4%	6	0.2%	24	4.6%	7
Huddinge	2.4%	6	0.9%	18	2.8%	8	0.6%	22
Mölndal	2.4%	7	0.6%	38	0.5%	12	11.2%	2
Sollentuna	2.2%	8	0.7%	34	0.0%	95-288	0.1%	66
Linköping	2.0%	9	1.5%	5	5.3%	6	2.3%	9
Järfälla	1.9%	10	0.7%	30	0.0%	92	0.7%	18

University R&D and/or company R&D within a municipality seems to explain the patent production for most of these municipalities. Two municipalities where this is not the case are Sollentuna and Järfälla. In order to further investigate this phenomena descriptively, table 3.3 is constructed.

Table 3.3: Accessibility between municipalities in own functional region (Nacka = 100%) and rank.				
	University R&D		Company R&D	
Stockholm	22.2%	29	9.6%	40
Göteborg	2.7%	57	48.1%	8
Lund	5.9%	47	5.1%	47
Uppsala	0.0%	200	0.01%	209
Västerås	0.0%	204-288	0.07%	175
Huddinge	41.1%	16	49.7%	6
Mölndal	83.4%	2	36.6%	16
Sollentuna	50.3%	9	41.7%	10
Linköping	0.0%	204-288	0.02%	210
Järfälla	34.9%	20	27.6%	22

Table 3.3 lists the intra-regional accessibilities to university and company R&D, in order to find some indication of knowledge flow from one municipality to another. The numbers in the table show the accessibility for the municipalities in relation to the municipality with the highest accessibility. For both university and company R&D this municipality is Nacka. Both Sollentuna and Järfälla have reasonably high accessibility to R&D, but it is hard to say if this can explain their patent production. It could be the case that the chosen model does not capture all variations in the patent production.

4.1 Model considerations and results on aggregated level

Before starting to interpret the regression results, an investigation must be conducted to check whether the OLS estimator is the most appropriate estimator of the parameters. The results of this investigation (presented in Appendix A) indicate that the data is collinear and also that the disturbances is heteroscedastic. The most obvious problem with multicollinearity is the large standard errors of the estimates. By using a ridge regression estimator the standard errors are reduced, but instead you get a biased estimator. A difficulty with ridge regression is to choose a proper value of *k* in the ridge regression estimator,

$$b_r = \left[X'X + kD\right]^{-1} X'y \,,$$

where D is a diagonal matrix containing the diagonal elements of $X'X$. Another way of getting rid of the multicollinearity problem is of course to skip variables that are causing the problem. The positive side of this is that the remaining parameter estimates are unbiased if the deleted variables in the model are of no significance. When the disturbances are heteroscedastic the OLS estimators are no longer efficient but the estimators retain their properties of unbiasedness and consistency. One way of dealing with heteroscedasticity is therefore to retain the OLS approach but make use of the appropriate expression for the variance-covariance matrix of the estimators. This gives

$$Var(b) = (X'X)^{-1} X'VX(X'X)^{-1}$$

where V is the variance-covariance matrix of the disturbances. White (1980) suggests that the diagonal elements in V should be estimated by the square of the corresponding OLS residual, that is $Var(\varepsilon_i) = \sigma_i^2$ by e_i^2 for all *i*. A nice feature of White's correction is that the values will be correct whether or not you have heteroscedasticity.

In order to interpret the effects of the explanatory variables on patent production I have decided to use the approach suggested by White (1980) and also to run several regressions with one or two omitted variables instead of using ridge regression. In table 4.1 the estimation results for six model specifications are listed.

Table 4.1 Estimation results of equation 2.7 and modifications of 2.7 (OLS with White's correction to avoid heteroscedasticity)

	R1	R2	R3	R4	R5	R6
(Constant)	1.1038 (4.68)	1.2145 (4.28)	1.0330 (4.34)	1.0836 (4.38)	0.9011 (3.88)	0.8071 (3.71)
Access to univ R&D, municip	0.0145 (2.93)	0.0181 (3.37)	0.0138 (2.87)	0.0164 (3.24)	0.0140 (2.88)	0.0160 (3.12)
Access to univ R&D, intra-reg	-0.0083 (-1.10)	0.0063 (3.11)	-0.0094 (-1.25)	-	-0.0091 (-1.22)	-
Access to univ R&D, inter-reg	0.0069 (1.61)	0.0116 (2.36)	-	0.0084 (1.85)	0.0030 (1.29)	0.0033 (1.33)
Access to comp R&D, municip	0.2090 (5.48)	0.1864 (4.62)	0.2129 (5.57)	0.1963 (4.89)	0.2119 (5.58)	0.1985 (4.86)
Access to comp R&D, intra-reg	0.0937 (2.28)	-	0.1059 (2.56)	0.0465 (4.62)	0.1015 (2.50)	0.0506 (5.10)
Access to comp R&D, inter-reg	-0.0397 (-1.30)	-0.0750 (-2.12)	0.0065 (0.44)	-0.0519 (-1.62)	-	-
Large population (>100 000)	8.7759 (2.10)	8.7554 (1.92)	8.9362 (2.15)	8.8704 (2.02)	8.7017 (2.12)	8.7830 (2.03)
Medium population (50 to 100 000)	3.2923 (2.46)	3.9488 (3.05)	3.2006 (2.33)	3.4592 (2.67)	3.1346 (2.33)	3.2689 (2.48)
Adjusted R^2	0.913	0.905	0.912	0.911	0.913	0.910
Multicollinearity	strong	weak	strong	weak	strong	no

Significant parameter estimates in bold (95% confidence level). T-values in parenthesis.
R1 = full model
R2 = without "Access to comp R&D, inter-reg"
R3 = without "Access to univ R&D, inter-reg"
R4 = without "Access to comp R&D, intra-reg"
R5 = without "Access to univ R&D, intra-reg"
R6 = without "Access to univ R&D, intra-reg" and "Access to comp R&D, inter-reg"
R7 = without separate intra- and inter-regional variables
Multicollinearity - strong: VIF≈10, weak: VIF≈3, no: VIF < 2.5

The first regression (R1) is on the full model according to equation 2.7. Unfortunately there is a serious multicollinearity problem, especially between the intra-regional and also to some extent between the inter-regional variables, which could explain the negative signs of the parameter estimates for "Access to univ R&D, intra-reg" and "Access to comp R&D, inter-reg". One feature of multicollinearity is that some variables may be overestimated (here "Access to comp R&D, intra-reg" and "Access to univ R&D, inter-reg") and others underestimated (here "Access to univ R&D, intra-reg" and "Access to comp R&D, inter-reg"). To check if the negative parameter estimates remain two regressions are conducted, where the positive intra-reg variable is removed in first regression (R2) and the positive inter-reg variable is removed in the second (R3). According to R2, the parameter value of "Access to univ R&D, intra-reg" now becomes positive and significant. The coefficient of "Access to comp R&D, inter-reg" in R3 is no longer negative. In accordance with the multicollinearity test performed on R1 (see appendix A) the multicollinearity problem has been reduced in R2 but not in R3.

To further establish that the intra-regional variables are the ones that are causing the most serious problems regression R4 and R5 are conducted. In R4 "Access to univ R&D, intra-reg" is removed and in R5 "Access to comp R&D, inter-reg" is deleted from the original model and the conclusion remains that the intra-regional variables are the most collinear variables. However, it is not possible to use more than one intra-regional (university or company) and one inter-regional variable (university or company) in order to completely get rid of the multicollinearity problem. In R6 both "Access to univ R&D, intra-reg" and "Access to comp R&D, inter-reg" are deleted from the model. Any other combination of intra- and inter-regional variables would also accomplish a low degree of or no multicollinearity. I have chosen to keep the pair that has the highest correlation with patent production, which also is resulting in the highest coefficient of determination.

According to table 4.1 the adjusted R^2 is above 90% for all regressions (R1-R6), which is remarkably high and puts trust in the model specification. The results indicate that local accessibility of both university and company R&D have positive effects on patent production. The result confirms the consensus result in the literature (see Anselin et al. 1997, among others). The importance of local accessibility to R&D on patent production seems to have at least a relation of 1 to 10 in favour of company R&D, regardless of what regression is used in table 4.1. According to R6 an increase of the local accessibility to university R&D by 100, increases the number of patents, on average, by 1.6 in a municipality. The corresponding increase of the local accessibility to company R&D raises the patent production by 19.85. If the commuting time within a municipality is 15 minutes, then the accessibility increase can be accomplished if the stock of university R&D increases by 135 man-years. Under the assumption that the university R&D effort in a municipality is 1000 man-years and the commuting time is 15 minutes, the commuting time must be reduced to 8.7 minutes in order to get the required accessibility increase. (See Appendix B for calculations.)

As been demonstrated in the discussion above it is difficult to separate the effects of the intra-regional and the inter-regional variables respectively due to the existence of multicollinearity. But accessibility to company R&D seems to be the most important one on intra-regional level and accessibility to university R&D is the dominating variable on inter-regional level. The parameter estimates of the inter-regional variables are however not statistically significant (95% confidence level). According to all regressions in table 4.1 it looks like inter-regional accessibility to university R&D has a stronger effect on patent production than intra-regional accessibility to university R&D. This is due to multicollinearity and is not true. A comparison of R2 and R5 reveals that it is rather the reverse. The result of the comparison is also more in line with theory, i.e. the importance of R&D on the patent production decreases with distance.

The municipalities with a population above 100 000 have, on average, almost nine more produced patents per year than the municipalities with a population below 50 000. The corresponding figure for the medium sized municipalities (population 50 to 100 000) is approximately between three and four.

4.2 Elasticities on aggregated level

Where in Sweden does a percentage increase of the accessibility have the largest percentage effect on patent production? The 10 municipalities with the biggest accessibility elasticities of the significant variables from regression R6 in table 4.1 are listed in table 4.2. The table also shows the predicted values and the residuals for the actual municipalities. (A complete list of the municipalities in Sweden can be found in Appendix C)

Table 4.2: Accessibility elasticities, predicted values and residuals. Top ten municipalities.

Local accessibility to university R&D				Local accessibility to company R&D				Intra-regional accessibility to company R&D			
Municip	Elast	Pred	Resid	Municip	Elast	Pred	Resid	Municip	Elast	Pred	Resid
Umeå	0.612	30.5	-21.5	Södertälje	0.827	45.8	-26.6	Partille	0.907	10.4	-2.1
Uppsala	0.571	79.1	-16.4	Mölndal	0.817	68.3	-31.5	Värmdö	0.851	9.3	-4.3
Lund	0.446	70.6	5.4	Sandviken	0.770	5.1	10.7	Staffanstorp	0.851	5.6	3.5
Göteborg	0.414	96.7	7.9	Karlskoga	0.712	3.2	2.7	Salem	0.848	8.4	-4.6
Linköping	0.381	32.9	-1.9	Stockholm	0.678	188.4	15.4	Kungälv	0.845	5.6	3.0
Solna	0.360	37.9	-11.6	Stenungsund	0.669	5.5	5.3	Tyresö	0.812	8.3	4.5
Luleå	0.300	13.0	3.8	Ludvika	0.667	2.7	8.6	Sundbyberg	0.806	13.2	-7.4
Huddinge	0.285	24.0	13.1	Västerås	0.666	34.0	27.8	Ekerö	0.788	6.9	-2.6
Skara	0.276	1.4	0.9	Avesta	0.666	3.7	-1.8	Nacka	0.787	24.7	-5.0
Lomma	0.264	8.5	5.9	Finspång	0.636	3.6	1.1	Burlöv	0.783	6.6	-3.5

In general it seems like increasing the accessibility to company R&D has a greater effect on patent production than increasing the accessibility to university research. It is interesting to notice that the top two municipalities for the three accessibilties in table 4.2 have negative residuals, i.e. these municipalities are achieving below what would be expected. Take Umeå as an example. The expected number of patents per year in Umeå is 30.5, but the actual number of patents per year is only 30.5 – 21.5 = 20.0. But if Umeå performs according to its prerequisites a 10% increase in the local accessibility to university R&D would increase the number of produced patents by 6.12%. The top ten elatsticities of the intra-regional accessibility to company R&D are all municipalities in functional regions where Stockholm, Göteborg and Malmö/Lund are situated.

Table 4.2 shows the percentage increase in patent production if the municipalities perform according to their prerequisites. But if the municipalities continue to perform as in the period when data was collected the elasticities presented in table 4.2 is not the best measure. One way to improve the elasticity measure is to use the information of how the municipalities have succeeded in the past. If for instance a municipality has an actual patent production that exceeds the expected by 10%, then the factor 1.1 is used to weight the elasticity. Table 4.3 presents the municipalities with the highest accessibility elasticities weighted by $Pat_i/Pat_{i\,pred}$.

Table 4.3: Weighted accessibility elasticities and elasticities computed at sample means					
Local accessibility to university R&D		Local accessibility to company R&D		Intra-regional accessibility to company R&D	
Lund	0.480	Ludvika	2.775	Alingsås	1.923
Skara	0.464	Sandviken	2.397	Vellinge	1.736
Uppsala	0.453	Karlskoga	1.314	Lerum	1.648
Göteborg	0.448	Stenungsund	1.311	Österåker	1.544
Lomma	0.446	Västerås	1.212	Lidingö	1.523
Huddinge	0.440	Höganäs	1.124	Staffanstorp	1.381
Luleå	0.387	Fagersta	1.007	Kungälv	1.302
Karlstad	0.368	Hammarö	0.989	Sollentuna	1.279
Linköping	0.359	Hudiksvall	0.973	Tyresö	1.258
Stockholm	0.276	Sundsvall	0.940	Mjölby	1.253
At sample means	0.157	At sample means	0.310	At sample means	0.185

Many of the municipalities in table 4.2 can also be found in table 4.3, but in different order and with another value of the elasticity. One striking feature of the results in table 4.3 is that the company accessibility elasticities have increased and the university elasticities have experienced a small decrease. Interesting to notice is that a small municipality like Ludvika has the highest elasticity (local accessibility to company R&D). The probable cause is that Swedish Transmission Research Institute AB (STRI), a high voltage laboratory and technology consulting company is located here.

Is it not possible to calculate a single elasticity for the different accessibilities? In the linear model the value of the elasticity is often estimated by computing it at sample means as

$$Elast_{access} = b_{access} \frac{\bar{x}_{access}}{\bar{y}}$$

The last row in table 4.3 shows the elasticities at sample means. Changes in local accessibility to company R&D have the greatest effect on patent production. On average, a 10 percent accessibility increase results in a 3.1 percent increase of the number of produced patents. This is twice as much as the corresponding increase from changes in local accessibility to university R&D.

4.3 Co-variation and population effects

Is there any co-variation between university and company R&D that affects the patent production? In addition to the RHS variables used in R6 (see table 4.1) the variable "(Access to univ R&D, municip)*(Access to comp R&D, municip)" is included in the model. According to the results presented as R7 in table 4.3 the parameter estimate of the co-variation variable is significant and the adjusted R^2 is increased from 0.910 (see table 4.1) to 0.928. The variables statistically significant in R6 are still significant in R7.

Table 4.4: Estimation results. Modifications of R6, table 4.1 (OLS with White's correction)		
	R7	R8
(Constant)	1.3789 (4.07)	-0,4077 (-0.98)
Access to univ R&D, municip	0.0106 (2.79)	0,0118 (3.21)
Access to univ R&D, inter-reg	0.0025 (1.18)	0,0023 (1.05)
Access to comp R&D, municip	0.1164 (2.78)	0,1310 (4.51)
Access to comp R&D, intra-reg	0.0567 (5.80)	0,0443 (4.97)
(Access to comp R&D, municip)* (Access to comp R&D, municip)	5.2749 (3.14)	-
Access to pop R&D, municip	-	0,1237 (4.67)
Large population (>100 000)	12.0446 (2.49)	-
Medium population (50 to 100 000)	5.1273 (4.32)	-
Adjusted R^2	0.928	0.933

Significant parameter estimates in bold (95% confidence level). T-values in parenthesis.
Note that (Access to univ R&D, municip)* (Access to comp R&D, municip) is standardised.
Note that the variables for accessibility to population were computed using population in thousands.
R7 = Regression with (Access to univ R&D, municip)* (Access to comp R&D, municip) included.
R8 = Regression when the variables for accessibility to population are included in the model.

Does the surrounding economic activity affect the municipalities' patent production? To check for this the RHS variables in R6 (table 4.1) are supplemented with local accessibility to population. Population is used as a proxy for the economic activity in a municipality. Other variables could be number in employment or wage sum. To avoid problems with multicollinearity the variables intra-regional and inter-regional accessibility to population were not included. The dummy variables were deleted of the same reason. It could be argued that the size of the population in a municipality only has an indirect effect on patent production. It is of course the case that most of the R&D is conducted at universities and companies that are mainly located in larger municipalities. But the size of a population is not an input in an innovation process. Thus, the population variable is only used as control. The results are presented as R8 in table 4.3. The population variable crowds to some extent out the effects of the R&D variables, but the variables are still significant.

4.4 Spatial autocorrelation

Besides checking whether OLS is best estimator or not it is also recommended to check for spatial autocorrelation. Spatial autocorrelation is a problem for the regression models when the error terms show a spatial pattern in which municipalities close together are more similar than municipalities that are far apart. Measuring the correlation among the neighbouring municipalities is done using spatial autocorrelation statistic Moran's *I*. Computation of

Moran's I is achieved by division of the spatial co-variation by the total variation. Resultant values are in the range from -1 to 1. The general formula for computing Moran's *I* is:

$$I = \frac{N \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} z_i z_j}{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} \sum_{i=1}^{N} z_i^2}$$

Where *z'*s are deviations, i.e. $z_i = y_i - y_{mean} = y_i - y_{i\,pred} = e_i$, N = number of municipalities, and $w_{ij} = 1$ if *i* and *j* are neighbours, 0 otherwise (instead of neighbours I have use municipalities within own functional region).

The test on the null hypothesis that there is no spatial autocorrelation between observed values over the *N* municipalities can be conducted based on the standardized statistic

$$Z(I) = \frac{I - E(I)}{SD(I)}$$

where

$$E(I) = -\frac{1}{N-1}$$

$$SD(I) = \sqrt{\frac{2}{\sum_i \sum_j w_{ij}}}$$

Calculations give the following results:

Moran's I	-0.03666
E(I)	-0.00348
SD(I)	0.030585
Z(I)	-1.08459

The Moran's I is significant and positive when the observed value of locations within a certain distance tend to be similar, negative when they tend to be dissimilar, and approximately zero when the observed values are arranged randomly and independently over space. Furthermore, the test statistic $Z(I) = 1.08 < 1.96$ for the 95% confidence level. Thus, there is no evidence for spatial autocorrelation.

4.5 Estimations for different industrial sectors

If possible, equation 2.7 is the first choice for estimation. The multicollinerarity problem is less severe on sector level, and for certain industrial sectors it is possible to estimate the full equation (2.7). When two variables are collinear I have chosen to keep the variable measuring the accessibility to company R&D. In table 4.5 the number of patents in sector *j* is regressed against the three accessibility measures for university R&D on aggregated level and the three accessibility measures for company R&D in sector *j*. The regressions are only conducted for sectors with a yearly average of patents above 50 in the period 1994-1999. A complete list of the industrial sectors is presented in Appendix D.

Table 4.5: Estimation results of equation 2.7 for different industrial sectors. (OLS with White's correction)

	G7	G11	G12	G13	G14	G15	G16
(Constant)	0.0105 (0.29)	0.0795 (4.98)	0.2317 (1.54)	0.0636 (0.85)	0.0469 (1.90)	0.0749 (4.33)	0.0468 (2.58)
Access to univ R&D, municip	0.0058 (10.22)	0.0004 (2.11)	0.0104 (2.57)	0.0035 (2.97)	0.0049 (6.23)	0.0005 (2.19)	0.0013 (3.69)
Access to univ R&D, intra-reg	-	0.0001 (1.59)	-	0.0014 (2.83)	0.0013 (2.61)	0.0003 (3.52)	0.0006 (2.68)
Access to univ R&D, inter-reg	0.0003 (0,66)	0.0002 (1.35)	-	0.0008 (1.17)	-	-0.0001 (-1.16)	-0.0002 (-1.00)
Access to comp R&D, municip	0.0459 (14.77)	0.1936 (6.37)	-0.4657 (-0.83)	0.3027 (17.16)	0.1232 (2.36)	0.1714 (4.88)	-0.6243 (-0.50)
Access to comp R&D, intra-reg	0.0206 (4.35)	0.0971 (1.62)	0.5585 (4.31)	0.0436 (1.86)	-0.0523 (-0.10)	0.0204 (1.59)	-3.3323 (-1.05)
Access to comp R&D, inter-reg	0.0036 (0.51)	-0.0173 (-0.40)	0.3731 (2.41)	-0.0016 (-0.10)	0.0142 (0.57)	0.0126 (1.13)	4.8675 (2.58)
Large pop (>100 000)	0.4914 (0.80)	0.5152 (2.41)	4.1218 (1.64)	0.4708 (0.44)	0.5558 (0.87)	0.3327 (0.87)	0.4358 (2.01)
Medium pop (50 to 100 000)	-0.0250 (-0.20)	0.2070 (2.97)	2.3682 (3.81)	1.7331 (4.20)	0.3500 (1.82)	0.0874 (0.83)	0.2334 (2.76)
Adjusted R^2	0.935	0.610	0.652	0.929	0.873	0.790	0.663

Significant parameter estimates in bold (95% confidence level). T-values in parenthesis.
G7 = Manufacture of coke, refined petroleum products and nuclear fuel, chemicals and chemical products
G11 = Manufacture of fabricated metal products, except machinery and equipment
G12 = Manufacture of machinery and equipment
G13 = Manufacture of office machinery, electrical machinery and communication equipment
G14 = Manufacture of medical, precision and optical instruments, watches and clocks
G15 = Manufacture of motor vehicles and other transport equipment
G16 = Manufacture of furniture

The adjusted R^2 is higher for sector G7 and G13 than it is on aggregated level. These two sectors are also the most R&D intensive (see Appendix D). A comparison of G7 and G13 reveals however a difference between the parameter values of local accessibility to company R&D. Both variables are in a high degree statistically significant but the coefficient in G13 is seven times higher than the corresponding coefficient in G7. The interpretation is that accessibility to company R&D matters but accessibility increases are seven times more effective on patent production in G13. In some industrial sectors there is only a minor R&D activity in the companies. This affects of course the effect that company R&D has on patent production. In these sectors the estimated model can explain between 60 and 70% of the variations in patent production. One exception is G12 where the company R&D activity is reasonably high, but then the local accessibility has no importance, which results in an adjusted R^2 equal to 65%.

Local accessibility to university R&D seems to have a stable positive effect on patent production, although the parameter estimates are very small. An increase of the accessibility by 100 will, on average, only increase the number of patents from 0.04 to 1.04 depending on industrial sector. The dummy variables handling the population size are of less importance on sector level than on aggregated level. When the total amount of patents are divided into the industrial sectors it is obvious that the difference between the number of patents produced in large municipalities (population > 100 000) and small municipalities (population < 50 000) must be lesser. As an implication it is harder to find evidence that the parameter estimate is not zero, i.e. to reject the null.

5. Conclusions

My effort here has been to investigate to what extent accessibility to university R&D and company R&D can explain patent production in Swedish municipalities. The results indicate that investments in company R&D have a greater impact on the innovative capacity than university R&D, although both are statistically significant the magnitude of the former is much higher. However, it could be the case that university R&D also affects the innovative capacity indirectly through its impact on company R&D. The output of university R&D is often published articles and papers, books etc. and not patents directly. To clarify the relation between university and company R&D a simultaneous approach is required. Thus, a further extension of the analysis conducted here is necessary. For this reason it is too early to form a policy that favour R&D investments in companies.

Furthermore, I have shown in accordance with the literature that spatial proximity matters for establishing a productive link between R&D efforts and the number of patent applications. By using the accessibility concept on three geographical levels it is clear that local accessibility strongly dominates the other two. Knowledge flows within a functional region, i.e. intra-regional accessibility to R&D, are also of some importance, but the sizes of these positive effects are smaller. In studies like this there are often statistical problems with spatial autocorrelation. If it is the use of the accessibility concept that solve these problems in my study are left for a separate paper.

The elasticity calculations at sample means conducted in this paper show that patent production is rather insensitive to changes in accessibility to R&D, i.e. it requires a lot of R&D and/or infrastructural improvements to accomplish patent applications. Nevertheless, there are municipalities that perform better than others and concentrated efforts could be worth while. Even so, the interesting issue to stress is why certain municipalities perform better/worse compared to their prerequisites.

The final output of an innovation process is not patent applications. Together with R&D efforts they are costs in the innovation process. Benefits from the process are measured when patents are commercialised and contributes to economic growth. Thus, further investigations to what extent patent applications contribute to economic growth are required.

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Appendix A

Is the OLS estimator the most proper estimator?

The following model has been estimated:

$$Pat_i = a + b_1 A_{iL}^{uR\&D} + b_2 A_{iR}^{uR\&D} + b_3 A_{iXR}^{uR\&D} + b_4 A_{iL}^{cR\&D} + b_5 A_{iR}^{cR\&D} + b_6 A_{iXR}^{cR\&D} + b_7 D_1 + b_8 D_2 + \varepsilon_i$$

1) Normality

Tests of Normality

	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Unstandardized Residual	0.229	288	0.000	0.712	288	0.000

a Lilliefors Significance Correction

Unstandardized Residual Stem-and-Leaf Plot

```
Frequency    Stem &  Leaf

   20.00 Extremes    (=<-3.7)
    1.00       -3 .  &
    5.00       -3 .  4&
    3.00       -2 .  9&
    6.00       -2 .  22&
    8.00       -1 .  568&
   40.00       -1 .  00000011111111112234
   71.00       -0 .  55555566667777777777888888999999999
   30.00       -0 .  000011122234444
   25.00        0 .  00011223444
   17.00        0 .  5556789
    6.00        1 .  02&
    8.00        1 .  569&
   10.00        2 .  0013&
    1.00        2 .  &
    3.00        3 .  &
   34.00 Extremes    (>=3.2)

Stem width:   1.00000
Each leaf:       2 case(s)

& denotes fractional leaves.
```

The results indicates that the error term is normally distributed

2) Multicollinearity

Correlations (Pearson)

	No of patents	Access to univ R&D, municip	Access to univ R&D, intra-reg	Access to univ R&D, inter-reg	Access to comp R&D, municip	Access to comp R&D, intra-reg	Access to comp R&D, inter-reg	Large pop	Medium pop
No of patents	1.000	0.831	0.286	0.200	0.892	0.319	0.127	0.552	0.207
Access to univ R&D, municip	0.831	1.000	0.066	0.108	0.723	0.147	0.139	0.572	0.073
Access to univ R&D, intra-reg	0.286	0.066	1.000	0.251	0.186	**0.935**	0.052	-0.016	0.244
Access to univ R&D, inter-reg	0.200	0.108	0.251	1.000	0.108	0.288	0.790	0.121	0.144
Access to comp R&D, municip	0.892	0.723	0.186	0.108	1.000	0.139	0.076	0.451	0.132
Access to comp R&D, intra-reg	0.319	0.147	**0.935**	0.288	0.139	1.000	0.056	0.021	0.264
Access to comp R&D, inter-reg	0.127	0.139	0.052	0.790	0.076	0.056	1.000	0.142	0.124
Large pop	0.552	0.572	-0.016	0.121	0.451	0.021	0.142	1.000	-0.075
Medium pop	0.207	0.073	0.244	0.144	0.132	0.264	0.124	-0.075	1.000

Note the high correlation between the two intra-regional variables.

Auxillary regressions. For instance "Access to univ R&D, municip" on LHS and the other explanatory variables on RHS.

Dependent variable	Tolerance	VIF
Access to univ R&D, municip	0.312	3.209
Access to univ R&D, intra-reg	**0.094**	**10.673**
Access to univ R&D, inter-reg	0.300	3.329
Access to comp R&D, municip	0.361	2.769
Access to comp R&D, intra-reg	**0.089**	**11.272**
Access to comp R&D, inter-reg	0.320	3.127
Large pop	0.645	1.551
Medium pop	0.882	1.134

Rule of thumb: "Tolerance" < 0.40 indicates that multicollinearity might be a problem.
Rule of thumb: VIF > 2.50 indicates that multicollinearity might be a problem.
The most serious problems occur with the intra-regional variables.

3) Heteroscedasticity

White's test: Auxillary regression according to White, in order to use R^2 to test for heteroskedasticity.

$$e_i^2 = \alpha + \beta Pat_i^2 + v_i$$

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,240(a)	,058	,054	84,00363

a Predictors: (Constant), YHATT2

$nR^2 \sim \chi^2_{d.f.}$ d.f = 1, n = 288. $nR^2 = 15.55 > 3.84$. It is possible to reject the null hypothesis that there is no heteroscedasticity (95% confidence level).

Appendix B

R&D stock = 1000 man-years
Time sensitivity parameter, within municipality = 0.02
Commuting time = 15 minutes

Increase in R&D to accomplish an accessibility increase = 100:

100/EXP(-0.02*15) = 134.9859

Increase in R&D to accomplish an accessibility increase = 100:

LN(EXP(-0.02*15)+100/1000)/(-0.02) = 8.668989

Appendix C

Elasticities, predicted values and residuals for the municipalities in Sweden

	Elasticities				
	Local accessibility to university R&D	Local accessibility to company R&D	Intra-regional accessibility to company R&D	Predicted value	Residual
0114 Upplands Väsby	0.000	0.025	0.624	10.1	-0.6
0115 Vallentuna	0.000	0.000	0.621	6.4	-2.7
0117 Österåker	0.000	0.066	0.605	5.0	7.8
0120 Värmdö	0.000	0.000	0.851	9.3	-4.3
0123 Järfälla	0.000	0.251	0.371	14.4	15.3
0125 Ekerö	0.000	0.000	0.788	6.9	-2.6
0126 Huddinge	0.285	0.116	0.402	24.0	13.1
0127 Botkyrka	0.000	0.099	0.553	13.2	9.3
0128 Salem	0.000	0.000	0.848	8.4	-4.6
0136 Haninge	0.000	0.000	0.649	13.3	-3.5
0138 Tyresö	0.000	0.026	0.812	8.3	4.5
0139 Upplands-Bro	0.000	0.000	0.466	5.0	-0.7
0160 Täby	0.000	0.076	0.546	14.3	12.7
0162 Danderyd	0.008	0.075	0.768	15.1	5.4
0163 Sollentuna	0.000	0.031	0.557	14.5	18.8
0180 Stockholm	0.255	0.678	0.010	188.4	15.4
0181 Södertälje	0.002	0.827	0.072	45.8	-26.6
0182 Nacka	0.000	0.010	0.787	24.7	-5.0
0183 Sundbyberg	0.006	0.014	0.806	13.2	-7.4
0184 Solna	0.360	0.106	0.386	37.9	-11.6
0186 Lidingö	0.000	0.080	0.755	9.8	10.0
0187 Vaxholm	0.000	0.000	0.660	4.7	-1.3
0188 Norrtälje	0.001	0.000	0.045	5.0	-1.2
0191 Sigtuna	0.000	0.049	0.245	5.9	-1.7
0192 Nynäshamn	0.000	0.037	0.438	1.9	2.0
0305 Håbo	0.000	0.000	0.349	4.0	-3.2
0319 Älvkarleby	0.000	0.525	0.041	3.0	-1.8
0360 Tierp	0.001	0.165	0.058	1.4	-1.1
0380 Uppsala	0.571	0.287	0.000	79.1	-16.4
0381 Enköping	0.000	0.000	0.050	1.9	2.6
0382 Östhammar	0.000	0.232	0.031	1.4	0.0
0428 Vingåker	0.000	0.121	0.000	1.2	-0.7
0461 Gnesta	0.000	0.000	0.578	2.4	-0.9
0480 Nyköping	0.014	0.226	0.012	6.7	-3.6
0481 Oxelösund	0.000	0.308	0.078	2.4	-2.1
0482 Flen	0.000	0.000	0.001	1.3	-0.5
0483 Katrineholm	0.000	0.000	0.007	1.2	3.0
0484 Eskilstuna	0.052	0.117	0.000	5.7	5.3
0486 Strängnäs	0.001	0.209	0.281	2.9	-0.4
0488 Trosa	0.000	0.017	0.571	2.5	1.0
0509 Ödeshög	0.000	0.000	0.052	0.9	-0.7
0512 Ydre	0.000	0.000	0.001	1.0	-0.8
0513 Kinda	0.000	0.000	0.085	0.9	-0.9
0560 Boxholm	0.000	0.017	0.103	1.0	-0.8
0561 Åtvidaberg	0.000	0.000	0.208	1.1	0.4
0562 Finspång	0.000	0.636	0.004	3.6	1.1
0563 Valdemarsvik	0.000	0.000	0.008	1.0	0.0
0580 Linköping	0.381	0.325	0.000	32.9	-1.9
0581 Norrköping	0.022	0.049	0.006	11.4	-4.5
0582 Söderköping	0.000	0.000	0.046	1.5	-1.0
0583 Motala	0.000	0.285	0.079	1.3	1.7
0584 Vadstena	0.000	0.000	0.125	1.0	-0.6
0586 Mjölby	0.000	0.008	0.301	1.2	3.9
0604 Aneby	0.000	0.000	0.002	1.0	-0.6
0617Gnosjö	0.000	0.000	0.000	0.9	2.4

0642 Mullsjö	0.000	0.063	0.070	1.1	-0.6
0643 Habo	0.000	0.029	0.127	1.1	-0.3
0662 Gislaved	0.000	0.000	0.000	1.0	2.3
0665 Vaggeryd	0.000	0.000	0.102	1.0	-0.7
0680 Jönköping	0.060	0.172	0.000	12.8	0.2
0682 Nässjö	0.000	0.000	0.001	0.9	-0.1
0683 Värnamo	0.000	0.000	0.000	0.9	3.6
0684 Sävsjö	0.000	0.000	0.002	0.9	-0.7
0685 Vetlanda	0.000	0.027	0.000	0.9	-0.2
0686 Eksjö	0.000	0.018	0.000	0.9	0.6
0687 Tranås	0.000	0.036	0.000	1.1	0.2
0760 Uppvidinge	0.000	0.000	0.023	0.9	0.0
0761 Lessebo	0.000	0.000	0.078	0.9	-0.9
0763 Tingsryd	0.000	0.000	0.041	0.9	-0.9
0764 Alvesta	0.000	0.000	0.169	1.0	-0.5
0765 Älmhult	0.000	0.000	0.000	1.0	0.2
0767 Markaryd	0.000	0.000	0.001	1.1	-0.3
0780 Växjö	0.107	0.288	0.000	6.8	-0.5
0781 Ljungby	0.000	0.000	0.012	0.9	2.2
0821 Högsby	0.000	0.000	0.005	0.9	-0.9
0834 Torsås	0.000	0.000	0.019	0.9	-0.9
0840 Mörbylånga	0.035	0.000	0.042	0.9	-0.2
0860 Hultsfred	0.000	0.000	0.003	0.9	-0.2
0861 Mönsterås	0.000	0.000	0.010	0.9	-0.5
0862 Emmaboda	0.000	0.000	0.008	0.9	0.6
0880 Kalmar	0.093	0.193	0.000	5.7	-1.4
0881 Nybro	0.000	0.000	0.051	0.9	-0.4
0882 Oskarshamn	0.000	0.137	0.000	1.0	-0.6
0883 Västervik	0.000	0.078	0.000	0.9	0.9
0884 Vimmerby	0.000	0.038	0.000	1.0	-0.6
0885 Borgholm	0.007	0.000	0.028	0.8	-0.5
0980 Gotland	0.006	0.005	0.000	4.1	-3.6
1060 Olofström	0.000	0.195	0.022	1.3	-0.5
1080 Karlskrona	0.071	0.168	0.002	5.4	-1.3
1081 Ronneby	0.123	0.171	0.038	1.3	0.5
1082 Karlshamn	0.000	0.385	0.006	1.7	2.2
1083 Sölvesborg	0.000	0.071	0.009	1.2	0.4
1214 Svalöv	0.043	0.381	0.054	7.4	-7.1
1230 Staffanstorp	0.000	0.000	0.851	5.6	3.5
1231 Burlöv	0.000	0.090	0.783	6.6	-3.5
1233 Vellinge	0.000	0.000	0.712	2.9	4.1
1256 Östra Göinge	0.000	0.000	0.008	1.2	-0.7
1257 Örkelljunga	0.000	0.000	0.189	1.7	-1.0
1260 Bjuv	0.000	0.447	0.127	5.2	-5.2
1261 Kävlinge	0.000	0.171	0.674	5.6	2.0
1262 Lomma	0.264	0.000	0.636	8.5	5.9
1263 Svedala	0.000	0.000	0.748	3.3	-1.6
1264 Skurup	0.000	0.000	0.509	1.7	1.5
1265 Sjöbo	0.000	0.000	0.495	1.7	0.3
1266 Hörby	0.000	0.000	0.580	2.1	-0.9
1267 Höör	0.000	0.000	0.528	1.8	-0.3
1270 Tomelilla	0.000	0.035	0.001	2.1	-0.8
1272 Bromölla	0.000	0.000	0.025	1.2	-0.7
1273 Osby	0.000	0.000	0.000	1.2	-0.5
1275 Perstorp	0.000	0.621	0.036	5.1	-3.1
1276 Klippan	0.000	0.000	0.269	2.5	-1.6
1277 Åstorp	0.000	0.035	0.309	2.9	-2.4
1278 Båstad	0.000	0.060	0.077	1.5	1.0
1280 Malmö	0.133	0.451	0.075	28.2	-0.5
1281 Lund	0.446	0.481	0.014	70.6	5.4
1282 Landskrona	0.000	0.322	0.111	6.3	-1.7
1283 Helsingborg	0.000	0.351	0.023	18.0	-0.5
1284 Höganäs	0.002	0.418	0.107	3.2	5.3
1285 Eslöv	0.001	0.128	0.677	4.5	-1.3
1286 Ystad	0.000	0.000	0.186	1.0	1.0
1287 Trelleborg	0.000	0.254	0.337	2.0	1.3
1290 Kristianstad	0.126	0.044	0.001	5.8	-1.6

1291 Simrishamn	0.027	0.028	0.002	1.3	-0.8
1292 Ängelholm	0.001	0.090	0.186	2.2	2.3
1293 Hässleholm	0.000	0.005	0.002	5.0	-1.1
1315 Hylte	0.000	0.068	0.010	1.0	-1.0
1380 Halmstad	0.082	0.138	0.000	5.7	2.8
1381 Laholm	0.002	0.029	0.033	1.3	1.2
1382 Falkenberg	0.000	0.000	0.000	1.4	1.6
1383 Varberg	0.001	0.000	0.000	5.2	-2.3
1384 Kungsbacka	0.020	0.013	0.595	11.0	4.2
1401 Härryda	0.000	0.231	0.721	17.7	-8.7
1402 Partille	0.000	0.013	0.907	10.4	-2.1
1407 Öckerö	0.000	0.000	0.712	2.8	0.5
1415 Stenungsund	0.002	0.669	0.179	5.5	5.3
1419 Tjörn	0.000	0.000	0.280	1.1	1.5
1421 Orust	0.000	0.000	0.243	1.1	-0.3
1427 Sotenäs	0.000	0.000	0.004	0.9	-0.1
1430 Munkedal	0.001	0.000	0.032	1.1	-0.9
1435 Tanum	0.000	0.000	0.000	0.9	0.3
1438 Dals-Ed	0.000	0.000	0.000	0.9	-0.9
1439 Färgelanda	0.000	0.000	0.039	1.1	-1.1
1440 Ale	0.000	0.319	0.552	6.4	-3.8
1441 Lerum	0.000	0.077	0.777	5.7	6.4
1442 Vårgårda	0.000	0.098	0.199	1.2	0.6
1443 Bollebygd	0.000	0.000	0.063	4.0	-3.5
1444 Grästorp	0.000	0.000	0.137	1.3	-1.0
1445 Essunga	0.000	0.000	0.045	1.4	-0.7
1446 Karlsborg	0.000	0.000	0.005	0.9	-0.4
1447 Gullspång	0.000	0.000	0.010	0.9	-0.9
1452 Tranemo	0.000	0.000	0.052	1.3	-0.1
1460 Bengtsfors	0.000	0.000	0.000	0.8	-0.7
1461 Mellerud	0.000	0.000	0.034	1.0	0.0
1462 Lilla Edet	0.000	0.000	0.451	1.5	-0.9
1463 Mark	0.002	0.054	0.408	1.6	2.1
1465 Svenljunga	0.000	0.023	0.063	1.4	-0.9
1466 Herrljunga	0.000	0.000	0.026	1.4	-0.2
1470 Vara	0.000	0.027	0.011	1.3	-1.2
1471 Götene	0.000	0.016	0.041	1.0	-0.7
1472 Tibro	0.000	0.000	0.022	0.9	-0.9
1473 Töreboda	0.000	0.000	0.051	0.9	-0.9
1480 Göteborg	0.414	0.390	0.096	96.7	7.9
1481 Mölndal	0.019	0.817	0.104	68.3	-31.5
1482 Kungälv	0.000	0.007	0.845	5.6	3.0
1484 Lysekil	0.171	0.000	0.011	1.3	0.0
1485 Uddevalla	0.012	0.000	0.040	5.0	-4.1
1486 Strömstad	0.073	0.000	0.000	0.9	-0.2
1487 Vänersborg	0.080	0.166	0.220	2.5	-0.6
1488 Trollhättan	0.004	0.485	0.006	9.6	-5.8
1489 Alingsås	0.012	0.042	0.500	1.9	5.4
1490 Borås	0.035	0.420	0.000	10.3	-1.3
1491 Ulricehamn	0.000	0.011	0.076	1.5	4.2
1492 Åmål	0.000	0.128	0.022	1.0	1.0
1493 Mariestad	0.000	0.384	0.003	1.4	-0.6
1494 Lidköping	0.000	0.332	0.002	1.5	1.1
1495 Skara	0.276	0.000	0.012	1.4	0.9
1495 Skövde	0.062	0.037	0.003	4.6	-1.6
1497 Hjo	0.000	0.000	0.009	0.9	-0.7
1498 Tidaholm	0.000	0.000	0.009	0.9	-0.6
1499 Falköping	0.000	0.025	0.006	1.0	0.2
1715 Kil	0.000	0.000	0.168	1.0	0.2
1730 Eda	0.000	0.000	0.003	0.8	0.2
1737 Torsby	0.000	0.000	0.000	0.8	0.0
1760 Storfors	0.000	0.000	0.090	1.0	-0.8
1761 Hammarö	0.000	0.452	0.119	1.9	2.3
1762 Munkfors	0.000	0.000	0.011	0.8	-0.5
1763 Forshaga	0.000	0.000	0.163	1.0	0.2
1764 Grums	0.000	0.001	0.122	0.9	-0.9
1765 Årjäng	0.000	0.000	0.000	0.8	-0.8

1766 Sunne	0.000	0.000	0.000	0.8	-0.5
1780 Karlstad	0.149	0.278	0.013	7.3	10.7
1781 Kristinehamn	0.000	0.197	0.051	1.1	0.2
1782 Filipstad	0.003	0.025	0.000	0.9	-0.5
1783 Hagfors	0.000	0.238	0.000	1.1	-0.2
1784 Arvika	0.000	0.136	0.000	1.0	1.5
1785 Säffle	0.000	0.208	0.009	1.1	0.7
1814 Lekeberg	0.000	0.000	0.054	0.9	-0.6
1860 Laxå	0.000	0.149	0.015	1.1	0.9
1861 Hallsberg	0.000	0.035	0.061	1.0	-0.8
1862 Degerfors	0.000	0.000	0.192	1.1	-0.8
1863 Hällefors	0.001	0.000	0.001	0.8	-0.3
1864 Ljusnarsberg	0.000	0.045	0.035	0.9	-0.4
1880 Örebro	0.093	0.086	0.001	11.9	-6.2
1881 Kumla	0.000	0.042	0.074	1.0	0.0
1882 Askersund	0.000	0.000	0.018	1.0	-0.8
1883 Karlskoga	0.000	0.712	0.000	3.2	2.7
1884 Nora	0.000	0.113	0.046	1.0	-0.5
1885 Lindesberg	0.000	0.176	0.023	1.1	0.4
1904 Skinnskatteberg	0.140	0.000	0.034	1.3	-1.1
1907 Surahammar	0.000	0.032	0.352	2.1	-1.6
1917 Heby	0.000	0.000	0.125	1.4	-0.8
1960 Kungsör	0.000	0.215	0.008	1.6	-0.8
1961 Hallstahammar	0.000	0.145	0.299	2.3	1.2
1962 Norberg	0.000	0.000	0.095	1.2	-0.5
1980 Västerås	0.013	0.666	0.000	34.0	27.8
1981 Sala	0.000	0.000	0.191	2.7	-1.6
1982 Fagersta	0.000	0.478	0.000	2.0	2.2
1983 Köping	0.015	0.000	0.033	1.4	0.6
1984 Arboga	0.002	0.108	0.022	1.4	-1.4
2021 Vansbro	0.000	0.000	0.000	0.8	-0.5
2023 Malung	0.000	0.000	0.000	0.8	-0.6
2026 Gagnef	0.000	0.036	0.098	1.0	0.0
2029 Leksand	0.000	0.000	0.031	0.9	-0.5
2031 Rättvik	0.000	0.000	0.026	0.8	-0.7
2034 Orsa	0.000	0.000	0.000	0.8	-0.5
2039 Älvdalen	0.000	0.000	0.000	0.8	-0.6
2061 Smedjebacken	0.000	0.151	0.123	1.3	1.4
2062 Mora	0.014	0.000	0.000	0.8	0.8
2080 Falun	0.025	0.245	0.016	5.8	-2.8
2081 Borlänge	0.073	0.195	0.024	5.9	-4.2
2082 Säter	0.000	0.000	0.092	1.1	-0.7
2083 Hedemora	0.197	0.041	0.108	1.6	-0.1
2084 Avesta	0.000	0.666	0.002	3.7	-1.8
2085 Ludvika	0.000	0.667	0.006	2.7	8.6
2101 Ockelbo	0.000	0.000	0.107	1.0	-1.0
2104 Hofors	0.000	0.133	0.106	1.2	0.8
2121 Ovanåker	0.000	0.000	0.000	0.8	0.7
2132 Nordanstig	0.000	0.017	0.009	0.9	0.0
2161 Ljusdal	0.000	0.000	0.000	0.8	-0.3
2180 Gävle	0.136	0.167	0.049	6.8	5.8
2181 Sandviken	0.002	0.770	0.020	5.1	10.7
2182 Söderhamn	0.000	0.042	0.000	0.9	0.4
2183 Bollnäs	0.000	0.000	0.000	0.8	0.7
2184 Hudiksvall	0.000	0.234	0.000	1.1	3.4
2260 Ånge	0.000	0.000	0.004	0.8	0.4
2262 Timrå	0.000	0.000	0.316	1.2	-1.0
2280 Härnösand	0.180	0.115	0.027	1.2	-1.0
2281 Sundsvall	0.068	0.479	0.000	9.0	8.7
2282 Kramfors	0.000	0.009	0.000	0.8	0.2
2283 Sollefteå	0.000	0.000	0.000	0.8	-0.2
2284 Örnsköldsvik	0.007	0.291	0.000	6.0	-2.6
2303 Ragunda	0.001	0.000	0.000	0.8	-0.8
2305 Bräcke	0.000	0.000	0.001	0.8	-0.6
2309 Krokom	0.000	0.000	0.024	0.8	0.2
2313 Strömsund	0.004	0.000	0.000	0.8	-0.6
2321 Åre	0.000	0.000	0.000	0.8	-0.5

2326 Berg	0.000	0.000	0.001	0.8	-0.8
2361 Härjedalen	0.000	0.000	0.000	0.8	-0.6
2380 Östersund	0.115	0.048	0.000	4.9	-2.5
2401 Nordmaling	0.000	0.000	0.031	0.8	-0.7
2403 Bjurholm	0.000	0.000	0.017	0.8	-0.8
2404 Vindeln	0.011	0.000	0.023	0.8	-0.7
2409 Robertsfors	0.000	0.092	0.013	0.9	-0.2
2417 Norsjö	0.000	0.000	0.001	0.8	-0.7
2418 Malå	0.000	0.000	0.000	0.8	-0.6
2421 Storuman	0.002	0.000	0.000	0.8	-0.6
2422 Sorsele	0.000	0.000	0.000	0.8	-0.8
2425 Dorotea	0.000	0.000	0.000	0.8	-0.8
2460 Vännäs	0.000	0.000	0.093	0.9	-0.4
2462 Vilhelmina	0.001	0.000	0.000	0.8	-0.6
2463 Åsele	0.000	0.000	0.000	0.8	-0.8
2480 Umeå	0.612	0.073	0.000	30.5	-21.5
2481 Lycksele	0.012	0.000	0.000	0.9	0.6
2482 Skellefteå	0.028	0.053	0.000	4.5	4.0
2505 Arvidsjaur	0.000	0.000	0.000	0.8	-0.8
2506 Arjeplog	0.000	0.000	0.000	0.8	-0.6
2510 Jokkmokk	0.002	0.000	0.000	0.8	-0.8
2513 Överkalix	0.000	0.000	0.000	0.8	-0.7
2514 Kalix	0.000	0.002	0.000	0.9	-0.6
2518 Övertorneå	0.000	0.000	0.000	0.8	-0.8
2521 Pajala	0.000	0.000	0.000	0.8	-0.8
2523 Gällivare	0.002	0.000	0.000	0.8	-0.8
2560 Älvsbyn	0.000	0.000	0.034	0.8	-0.7
2580 Luleå	0.300	0.387	0.000	13.0	3.8
2581 Piteå	0.105	0.413	0.018	1.8	1.2
2582 Boden	0.052	0.000	0.126	1.0	0.2
2583 Haparanda	0.135	0.000	0.000	1.0	-0.8
2884 Kiruna	0.127	0.118	0.000	1.1	-0.9

Appendix D

Description and statistics of the industrial sectors

Group	Patents per year (1994-1999)	R&D man year (1994-1999)	Description	SNI codes
G1	0.48	26.2	Agriculture. forestry and fishing	1, 2, 5
G2	0.15	8.6	Mining	10, 11, 12, 13, 14
G3	6.40	26.2	Manufacture of food and tobacco products	15, 16
G4	12.70	3.6	Manufacture of textiles. clothing an leather products	17, 18, 19
G5	3.69	1.9	Manufacture of wood and wood products. except furniture	20
G6	16.01	105.9	Manufacture of paper. paper products. publishing and printing	21, 22
G7	190.01	996.3	Manufacture of coke. refined petroleum products and nuclear fuel. chemicals and chemical products	23, 24
G8	35.75	19.1	Manufacture of rubber and plastics products	25
G9	11.71	5.4	Manufacture of other non-metallic mineral products	26
G10	18.45	57.6	Manufacture of basic metals	27
G11	59.93	34.9	Manufacture of fabricated metal products. except machinery and equipment	28
G12	475.23	133.0	Manufacture of machines and equipment	29
G13	363.76	438.7	Manufacture of office machinery. electrical machinery and communication equipment	30, 31, 32
G14	163.49	125.4	Manufacture of medical. precision and optical instruments. watches and clocks	33
G15	72.97	161.6	Manufacture of motor vehicles and other transport equipment	34, 35
G16	62.53	0.3	Manufacture of furniture	36
G17	-	0.5	Recycling	37
G18	0.13	13.4	Distribution of water and electricity	40
G19	1.24	13.9	Construction	45
G20	0.04	45.6	Wholesale and retail trade	50, 51, 52
G22	0.02	58.2	Transport. storage and communications	60, 61, 63, 64
G25	-	31.1	Computer and related activities	72
G26	-	471.1	Research and development	73
G27	0.01	67.7	Other business activities	74
G28	-	1.3	Education	80
G29	-	3.5	Health and social work	85
G30	1.37	8.5	Other community. social and personal service activities	90, 91, 92, 93
Tot	1496.03	2859.5		