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Human capital, R&D and Regional Export

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Abstract

The main purpose in this paper is to study to what extent accessibility to R&D and human capital can explain regional export. Therefore a knowledge production function is estimated both on aggregated level and for different industrial sectors. The outputs of the knowledge production are export value and exports above a certain price in Swedish municipalities from 1997 to 1999. In order to account for geographical proximity, the explanatory variables are expressed as accessibilities to R&D and human capital. The total accessibility is decomposed into local, intra-regional and inter-regional accessibility to R&D. The estimations are conducted with quantile regressions since the distributions of the dependent variables are highly skewed. Due to problems with multicollinearity it is not easy to tell if the variations in the municipalities' exports are explained by human capital or company R&D. But the results in the paper indicate that accessibility to human capital has the greatest positive effects. The value of exported products is mainly affected by local accessibility to human capital (and company R&D). The intra- and inter-regional accessibilities play a more important roll when the number of high valued products in Swedish municipalities is the output.

Keywords: knowledge production, R&D, human capital, exports, quantile regression

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1. Introduction

Many studies of innovation tend to focus on the explanatory power of R&D expenditure (see Acs & Audretsch, 1989, among others). These studies use R&D expenditure or R&D effort as an input variable in a knowledge production function (Griliches, 1979). Other studies, following Lucas (1988), have identified the importance of human capital in economic growth (Glaeser et al 1995 and Gemmell 1996). Glaeser found that level of education is closely related to subsequent income and population growth. Simon (1998) also found a positive relationship between level of human capital and employment growth. There are however very few empirical studies that focus on the role of human capital in innovation and economic growth. Feldman (2000) assumes that highly educated people tend to produce more innovations and subsequent regional income and population growth. Following Jacobs (1961) and Lucas (1988), Florida & Lee (2001) showed that regional innovation (measured by the number of patents issued) is positively and significantly related to human capital (measured by the percentage of people with a bachelor's degree and above) and diversity.

The importance of geographical proximity on knowledge diffusion has been revealed in several studies (Jaffe, 1989; Jaffe et al., 1993; Feldman, 1994; Audretsch & Feldman, 1996). 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. There are several possible ways to measure geographical proximity. 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.

In Gråsjö (2004) the accessibility concept was used in a knowledge production framework. The output of the knowledge production was the number of patent applications in Swedish municipalities from 1994 to 1999. In order to account for proximity, the explanatory variables were expressed as accessibilities to university and company R&D. The total accessibility was also decomposed into local, intra-regional and inter-regional accessibilities. The consensus in the literature is that both university and company R&D have positive effects on patent production (see Anselin et al. 1997; Acs et al 2002, among others). Acs et al (2002) use data based on 125 US Metropolitan Areas (MSAs) in a knowledge production framework with patents and new product innovations as dependent variables. Their empirical findings show a clear dominance of company R&D over university research. However, this dominance is not so accentuated for new product innovations. This pattern is also replicated for research spillovers from surrounding areas; university R&D being more important for new product innovations and company R&D being the dominant factor for patents. The empirical findings in Gråsjö (2004) do to some extent support the results in Acs et al (2002). Local accessibility to company R&D is undoubtedly the dominating variable explaining patent production in Sweden. But while Acs et al. (2002) find statistically significant effects of local university research for the MSAs in US, local accessibility to university R&D for Swedish municipalities is of no importance.

This raises a number of questions: Is university R&D still ineffective if another output is used in the knowledge production process and is local company R&D still the dominating explanatory variable? Is accessibility to R&D the appropriate input variable or is accessibility to human capital (measured by people with a bachelor's degree and above) a better choice? Is there any evidence for productive knowledge flows between municipalities if other variables than patents and R&D efforts are used as outputs and inputs in the innovation process?

Although patents (granted patents as well as patent applications) are commonly used as proxies for the output of the innovation process, they do not by them selves generate economic growth. The classical definition of an innovation stresses introduction on the market. Thus, market penetration (or commercialization) distinguishes invention from innovation. If a firm also succeeds in introducing a product on the export market it implies a successful market penetration. Therefore export value or exports of high valued products could be useful measures of the innovative capacity in a region. Even though exports are not usually used as an output of an innovation process, it is a widespread agreement that knowledge is one of the crucial ingredients of innovation and in turn the main bases of international competitiveness and hence of successful export performance. Knowledge is therefore part of a good circle leading to innovation, competitiveness and exports. Exports and trade in their turn are major vehicles for the sharing and transfer of international knowledge.

This paper has the following main questions in focus:

- To what extent can accessibility to university and company R&D explain exports (measured by export value or exports of high valued products) in Swedish municipalities?
- Is it R&D effort or is it the presence of a well educated population that best explains the exporting performance (measured by export value or exports of high valued products) of a municipality?

In order to answer these questions a knowledge production function is estimated both on aggregated level and for different industrial sectors. The model used for the knowledge production function and the accessibility concept is presented in the next section. Section 3 presents the data and section 4 contains a discussion of the choice of an appropriate estimation method. In section 5 the estimation results from the regressions are presented. The paper ends with the main conclusions of the empirical findings.

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 and human capital are used instead of R&D effort. Furthermore, instead of patents, export value and number of high valued export products are used as outputs.

The accessibility of location i to it self and to $n-1$ surrounding locations is defined as the sum of its internal accessibility to a given opportunity X and its accessibility to the same opportunity in other locations (not only neighbours),

$$A_i^X = x_1 f(c_{i1}) + ... + x_i f(c_{ii}) + ... + x_n f(c_{in}) \quad (2.1)$$

where A_i^X is the total accessibility of location *i*. x_i is a measure of an opportunity *X*, which can be an opportunity such as R&D efforts in universities and companies. *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,

$$f(c_{ij}) = \exp\{-wt_{ij}\} \quad (2.2)$$

where t_{ij} is the time distance between location *i* and *j*, and *?* is a time sensitivity parameter. The value of *?* in (2.2) depends on if the interaction is local, intra-regional (between locations in a region), or inter-regional (location *i* and *j* in different regions). It is apparent that the accessibility value may improve in two ways, either by an increase in the size of the opportunity, x_j, or by a reduction in the time distance between location *i* and *j*. If the total accessibility to a specific opportunity is decomposed into local, intra-regional and inter-regional, then

$$A_i^X = A_{iL}^X + A_{iR}^X + A_{iOR}^X \quad (2.3)$$

where

$A_{iL}^X = x_i \exp\{-w_L t_{ii}\}$, local accessibility to opportunity *X* for location *i*

$A_{iR}^X = \sum_{r \in R,\, r \neq i} x_r \exp\{-w_R t_{ir}\}$, intra-regional accessibility to opportunity *X* for location *i*

$A_{iOR}^X = \sum_{k \notin R} x_k \exp\{-w_{OR} t_{ik}\}$, inter-regional accessibility to opportunity *X* for location *i*

j defines locations within the own region *R*, and *k* defines locations in other regions.

The accessibility concept expressed in Equation (2.3) has several advantages. Firstly, it incorporates "global" spillovers and does not only account for the impact from neighbours or locations within a certain distance band. Secondly, the separation of the total effect into local, intra-regional and inter-regional spillovers captures potential productive knowledge flows between locations and makes the inferential aspects more clear. Thirdly, distance is often measured by the physical distance, but a better way to measure it is to use the time it takes to travel between different locations (Beckman, 2000). Time distances are also crucial when it comes to attend to business meetings and also to spatial borders of labour markets (see Johansson & Klaesson, 2001, for the Swedish case).

The opportunities used in this paper are population with a bachelor's degree and above (at least three years of university studies) and conducted R&D work in Swedish universities and companies. When the accessibility variables are calculated they can be entered in a knowledge production function. The standard choice of the functional form is often a version of Cobb-Douglas. However, it could be argued that the various accessibilities are most probably perfect substitutes and hence the implication of Cobb-Douglas that one zero in inputs is enough for zero output does not make sense. Therefore an additive linear functional form is used to model the knowledge production,

$$y_i = a + A_{iL}^{x} b_1 + A_{iR}^{x} b_2 + A_{iOR}^{x} b_3 + u_i \qquad (2.4)$$

As dependent variables 1) the export value and 2) the number of exported products with a price greater than 1000 SEK per kg in municipality *i* are used. With 1000 SEK as a cut off value, approximately 13% of the products are above this limit. Local, intra-regional and inter-regional accessibility to 1) university R&D, 2) company R&D and 3) people with a bachelor's degree and above are the explanatory variables. Intuitively, the number of high valued export products is a better ouput measure of a knowledge production process than total export value. Hence, the innovative achievement is greater if a municipality has for instance two export products with a total value of 5000 SEK instead of one export product with a value of 5000 SEK. In addition, 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. The hypothesis is that municipalities with large populations have an economic activity that exceeds smaller municipalities' and this ought to affect the output. In the accessibility calculations the time sensitivity parameter value $?_L$ is set to 0.02, $?_R$ to 0.1 and $?_{OR}$ 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. It could perhaps look strange that the intra-regional accessibilities have the highest parameter value (? $_L$ = 0.02). But the intra-regional commuting trips, which are in the time span from 15 to 45 minutes, are the ones that are most time sensitive. That is, increased commuting time in this time span will hamper the propensity to travel the most.

In order to answer the questions outlined in section 1, the first choice would be to estimate Equation (2.4) with a single regression using export as the dependent variable and accessibility to university R&D, company R&D and human capital on all three geographical levels as exogenous variables. This is, however, not possible because of problems with multicollinearity, especially between the intra-regional variables. Therefore two separate specifications are estimated, one with the R&D variables and the other with human capital as exogenous variables. The following equation is estimated for the R&D variables

$$Exp_i = a + b_1 A_{iL}^{uR\&D} + b_2 A_{iXR}^{uR\&D} + b_3 A_{iL}^{cR\&D} + b_4 A_{iR}^{cR\&D} + b_5 D_1 + b_6 D_2 + u_i \qquad (2.5)$$

where $Exp_i =$ export value and number of export products with a prise above 1000 SEK per kg in municipality *I*, *uR&D* = university R&D in man-years and *cR&D* = company R&D in man-years. The other notations are as before. Any other combination of intra- and inter-regional variables would also accomplish a low degree of multicollinearity (see Gråsjö, 2004, for further details). I have chosen to keep the pair that has the highest correlation with the export variables. To estimate the relationship between exports and accessibility to human capital the following equation is used

$$Exp_i = a + b_1 A_{iL}^{hc} + b_2 A_{iR}^{hc} + b_3 A_{iXR}^{hc} + b_4 D_1 + b_5 D_2 + u_i \qquad (2.6)$$

where *hc* (human capital) is the notation for the number of people in age 16-74 with a bachelor's degree and above. In order to get a direct comparison of the importance of human capital, company and university R&D on exports and to avoid the multicollinearity problem, one solution is to express the variables of interest with respect to some size variable. However, the intra-regional and inter-regional variables will then not make any sense and therefore only local accessibilties are used in the specification

$$\frac{Exph_i}{Exp_i} = \frac{A_{iL}^{hc}}{Pop_i} b_1 + \frac{A_{iL}^{cR\&D}}{Pope_i} b_2 + \frac{A_{iL}^{uR\&D}}{Pope_i} b_3 + u_i \qquad (2.7)$$

where $Exph_i$ = export value for products with a price > 1000 SEK per kg, Pop_i = the number of people in age 16-74 in municipality i and $Pope_i$ = the number of people in age 16-64 gainfully employed with place of work in municipality i. The choice of $Pope_i$ as a scaling factor is motivated by the fact that company and university R&D are registered by workplace. The estimation results of (2.6), (2.7) and (2.8) are presented in section 5.

3. Data and descriptive statistics

Statistics Sweden collects data on companies' exports and performed R&D in universities and companies. National Road Administration in Sweden is the data source when it comes to commuting time between and within Swedish municipalities.

- Export value is a yearly average of the total export in SEK during the period of 1997-1999 in Swedish municipalities.
- 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 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 for the municipalities in Sweden						
Variable	# munic	Mean	Median	Std. dev.	Min	Max
Export value (10^9 SEK)	288	2.236	0.720	5.507	0.00086	48.43
No of products, export price > 1000 SEK per kg	288	60.09	28.67	88.37	0.667	727.7
(value of products with export price > 1000 SEK per kg) / (export value) in %	288	9.54	1.48	17.4	0.005	96.4
Access to univ R&D, munic	288	52.53	0	320.8	0	3012
Access to univ R&D, intra-reg	288	114.9	1.726	301.0	0	1990
Access to univ R&D, inter-reg	288	96.49	22.64	164.1	0.00049	1023
Access to comp R&D, municip	288	8.339	0.001	46.34	0	643.8
Access to comp R&D, intra-reg	288	19.47	0.641	50.91	0	383.3
Access to comp R&D, inter-reg	288	13.89	7.390	19.34	0.00010	168.2
Access to hum cap, munic	288	1755	477.3	5699	1.562	82442
Access to hum cap, intra-reg	288	3280	399.1	8172	0	56610
Access to hum cap, inter-reg	288	2948	2166	2954	0.031	20611
Access to hum cap, munic per 1000 inhabitants	288	53.42	44.26	35.81	0.080	312.8
Access to univ R&D, munic per 1000 employed	288	0.892	0	4.325	0	39.35
Access to comp R&D, munic per 1000 employed	288	0.251	0.00018	0.816	0	9.625
Large pop (>100 000)	288	0.038	0	0.192	0	1
Medium pop (50 to 100 000)	288	0.125	0	0.331	0	1

Note the large differences between the mean and the median for all variables. This is especially troublesome for the variables that are treated as endogenous in the regressions. If the distribution of the dependent variable is skewed with a few very influential variables an OLS regression gives biased results.

4. Choice of estimation method

In Appendix 1 the distributions of the dependent variables are analyzed graphically. It is easy to see that the distributions are skewed and have outliers. One way of dealing with highly influential outliers is to use quantile regression as an alternative to OLS. The quantile regression method has the important property that it is robust to distributional assumptions. The quantile regression estimator gives less weight to outliers of the dependent variable than OLS, which weakens the impact outliers might have on the results.

There are also theoretical advantages with quantile regressions. The municipalities are most likely heterogenous in their abilities to produce patents and export products. Thus the effects of the variables explaining the abilities do not have to be and probably are not the same for all municipalities. It could be the case that the municipalities where the value of the exports or the number of produced patents are low do not experience the same effect from an accessibility increase of highly skilled labour as the municipalities where the value of exports or the patenting activity is high. OLS cannot account for heterogeneity of this kind. OLS assumes that the conditional distribution of the export values or the number of patents, given the set of municipality characteristics, is homogenous. This implies that no matter what point on the conditional distribution is analyzed, the OLS estimates of the relationship between the dependent variable and the regressors are the same. OLS regression estimates the conditional mean of the dependent variable as a function of the explanatory variables. In contrast, quantile regression enables the estimation of any conditional quantile of the dependent variable as a function of the explanatory variables. By estimating the marginal effects of the explanatory variables for different quantiles, a more complete description of the relationship between dependent and explanatory variables is achieved.

Originally, quantile regressions were suggested by Koenker and Basset (1978) as a robust regression technique alternative to OLS for the case when the errors are not normally distributed. The quantile regression model specifies the conditional quantile as a linear function of covariates. For the ?th quantile, a common way to write the model (see, e.g. Buchinsky, 1998) is

$$y_i = x_i' b_q + e_{qi}, \qquad (4.1)$$

where *ß?* is an unknown vector of regression parameters associated with the *?*th quantile, x_i is a vector of independent variables, y_i is the dependent variable and *e?i* is an unknown error term. The *?*th conditional quantile of y given x is $Q_q(y_i|x_i) = x_i' b_q$ and denotes the quantile of y_i, conditional on the regressor vector x_i. The only necessary assumption concerning *e?i* is *Q?(e?i|xi)* = 0. The *?*th regression quantile (0 < *?* < 1) of *y* is the solution to the minimization of the sum of absolute deviations residuals

$$\min_b \frac{1}{n}\left(\sum_{i:y_i \geq x_i' b} |y_i - x_i' b| q + \sum_{i:y < x_i' b} |y_i - x_i' b| (1-q) \right) \qquad (4.2)$$

Different quantiles are estimated by weighting the residuals differently. For the median regression, all residuals receive equal weight. However, when estimating the 75th percentile, negative residuals are weighted by 0.25 and positive residuals by 0.75. The criterion is minimized, when 75 percent of the residuals are negative. In contrast to OLS, equation (4.2) cannot be solved explicitly since the objective function is not differentiable at the origin, but it can be solved with linear programming (see e.g. Buchinsky 1998).

A method of Koenker and Bassett (1982) and Rogers (1993) is generally used to estimate the variance–covariance matrix of the coefficients and generate estimates of regression coefficient standard errors. However, this method tends to underestimate standard errors for data sets with heteroscedastic error distributions (Rogers 1992). It is therefore important to use some other method for estimating standard errors, such as bootstrap re-sampling techniques. In this paper, standard errors will be obtained by bootstrapping the entire vector of observations (Gould 1992). When the bootstrap resampling procedure is used, only estimates of standard error and significance levels are affected, with estimates of quantile regression coefficients remaining unchanged.[2]

Note that quantile regression is not the same as applying OLS to subsets of the data produced by dividing the complete data set into different quantiles of the dependent variable. This way of handling the problem would initiate a truncation on the dependent variable and a sample selection bias and will result in a procedure where not all of the data are being used for each estimate. In contrast, for each quantile regression estimate all of the data are being used, some observations, however, get more weight than others.

When the data is dived into industrial sectors, there are municipalities that don't have any high valued export in some of the sectors. Thus, the number of high valued export products is a censored variable for some of the industrial sectors. The remedy is ordinarily to use a tobit specification, but the censored dependent variable does not at all influence the results for conditional quantiles above the censoring threshold (zero). Of course, this is not true for the conditional mean used in OLS. Powell (1984, 1986) has proposed an estimator that enables

[2] The procedure is called the design matrix bootstrap, where pairs (x_i,y_i), i = 1,..., n are drawn at random from the original observations with replacement. For each of these samples drawn, an estimator of the parameters vector, ß? is recomputed. Repeating this procedure Z times yields a sample of Z parameter vectors whose sample covariance matrix constitutes a valid estimator of the covariance matrix of the original estimator. This procedure is automated in the Stata statistical package.

the estimation of all conditional quantiles when the data is censored. Powell's method is, however, not used in this paper because the problem with the zeroes only emerges for one of the estimated sectors (and not on aggregated level).

The number of exported products is an example of count data and then the choice is often the Poisson regression model or the negative binomial. In the case of bounded counts, when the response can be viewed as the number of successes out of a fixed number of trials, the standard distribution for regression modelling is the binomial. In the case of unbounded counts, Poisson regression models are standard. The number of produced patents in a municipality is unbounded (at least in theory), so in that sense Poisson is a better choice. But a problem with the Poisson regression model is its restrictiveness for count data. The fundamental problem is that the distribution is parameterised in terms of a single scalar parameter (the mean, μ) so that all moments of y are a function of μ. In contrast, the normal distribution has separate parameters for location (μ) and scale (s^2). Even though there are developments of the standard Poisson regression models (see e.g. Cameron & Trevedi, 2001) that are less restrictive I am going to stick to the quantile regression model in this study. [3]

The quantile regression technique has been widely used in the past decade in many areas of applied econometrics. Applications include investigations of earnings mobility (Eide & Showalter, 1999), educational attainment (Eide and Showalter 1998) and estimation of factors of high risk in finance (Chernozhukov & Umantsev, 2001). Appplications concerning regional innovation systems and knowledge production are not that easily found. One exception is Audretsch, Lehmann & Warning (2004) in their examination of locational choice as a firm strategy to access knowledge spillovers from universities, using a data set of young high-technology start-ups in Germany.

In the regressions that follow in the next section OLS results together with quantile regression results are presented for comparison reasons.

[3] According to Cameron & Trevedi (2001), the restrictiveness for count data manifests itself in many applications when a Poisson density predicts the probability of a zero count to be considerably less than is actually observed in the sample. This is termed the excess zeros problem, as there are more zeros in the data than the Poisson predicts. A second and more obvious way that the Poisson is deficient is that for count data the variance usually exceeds the mean (overdispersion), which will lead to deflated standard errors. The Poisson instead implies equality of variance and mean (equidispersion).

5. Regression results

The tables in section 5 contain estimation results of the regressions for quantile Q10, Q25, Q50, Q75, Q90 and also OLS with White's robust standard errors. In order to solve the heteroscedsticity problem for the quanitle regressions, bootstrap with 3000 replications are conducted. The analyses are carried out both on aggregated level and for three industrial sectors:

- Manufacture of refined petroleum products and chemical products
- Manufacture of machinery and equipment
- Manufacture of office machinery, electrical machinery and communication equipment

The selection of the three sectors is based on both total export value and total number of high valued export products. All the industrial sectors with some registered export are presented in Appendix 4.

5.1 Export and accessibility to R&D (Eq. 2.5)

Table 5.1 shows the effects of accessibility to university and company R&D on export values for aggregated data.

Table 5.1: Marginal effects of R&D on exports value (10^9 SEK) for Swedish Municipalities (Equation 2.5). Aggregated level

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	0.071 (4.63)	0.188 (4.83)	0.416 (7.04)	1.153 (6.07)	2.866 (5.69)	1.127 (6.74)
Access to univ R&D, municip	ns	ns	ns	ns	ns	ns
Access to univ R&D, inter-reg	ns	ns	ns	ns	ns	ns
Access to comp R&D, municip	ns	ns	ns	0.132 (1.99)	0.156 (2.44)	0.046 (2.17)
Access to comp R&D, intra-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	3.03 (2.12)	ns	5.085 (2.07)	ns	ns	5.335 (3.63)
Medium population (50 to 100 000)	0.696 (2.38)	0.886 (2.90)	1.597 (2.52)	3.805 (2.75)	ns	3.817 (2.31)
Pseudo R^2, Adj R^2	0.1689	0.202	0.272	0.337	0.449	0.456
Quantile value, mean value (dependent value)	0.080	0.264	0.720	2.043	4.765	2.236

Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

It is only local accessibility to company R&D that can explain the variations in export value for Swedish municipalities. The parameter estimates are positive and significant for municipalities with total export values corresponding to Q75 and Q90 of the conditional distribution. An accessibility increase of 10 raises the export value by 1.32 and 1.56 billion SEK, respectively.

In Table 5.2 the output measure is changed to number of export products with price above 1000 SEK per kg. The intra-regional effect is positive and statistically significant over the whole conditional distribution, with the largest effects in the upper tail of the distribution. Inter-regional accessibility to university R&D plays also a roll in the upper tail (Q75 and Q90).

Table 5.2: Marginal effects of R&D on number of high valued export products for Swedish municipalities (Equation 2.5). Aggregated level

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	3.267 (4.35)	7.090 (6.71)	13.68 (5.35)	27.71 (8.31)	47.95 (7.32)	19.27 (8.48)
Access to univ R&D, municip	ns	ns	ns	ns	ns	0.046 (2.48)
Access to univ R&D, inter-reg	ns	ns	ns	0.140 (4.66)	0.131 (3.98)	0.080 (3.31)
Access to comp R&D, municip	0.580 (3.34)	0.668 (3.32)	0.667 (1.99)	ns	ns	0.520 (4.80)
Access to comp R&D, intra-reg	0.288 (3.19)	0.385 (4.85)	0.497 (4.44)	0.683 (4.65)	0.633 (4.04)	0.517 (6.75)
Large population (>100 000)	123.4 (3.26)	139.7 (5.03)	136.4 (3.04)	ns	326.5 (3.35)	161.7 (4.75)
Medium population (50 to 100 000)	34.98 (3.83)	55.66 (4.01)	79.98 (5.78)	101.4 (5.54)	117.3 (6.52)	80.76 (8.14)
Pseudo R^2, Adj R^2	0.325	0.388	0.475	0.592	0.688	0.815
Quantile value, mean value (dependent variable)	5.3	11.67	28.67	66.75	167.4	60.09

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

Increasing local accessibility to company R&D has a proved effect only for the lowest quantiles. OLS shows a misleading significance for local accessibility to university R&D. This is an illuminating example on the weakness of OLS since a deletion of the nine highest observations of the dependent variable eliminates the significance. The parameter estimate shrinks to 0.0005 and the t-value to 0.04 (see Appendix for further details). In Gråsjö (2004) it was evident that local university R&D was of no importance on patent production in Swedish municipalities. The pattern is repeated in this paper when the output is export value or high valued exports. Thus the positive effects from university R&D found in US (Acs et al 2002) cannot be repeated.

The multicollinerarity problem is less severe on sector level, but when two variables are collinear I have chosen to keep the variable measuring the accessibility to company R&D. The export value or the number of high valued export products in sector *j* is regressed against the accessibility measures for university R&D on aggregated level and the three accessibility measures for company R&D in sector sector *j*. The proportion of municipalities with no produced patents during the investigated period is of course increased on sector level. Thus the censoring problem is more pronounced and as a consequence the interpretations when the quantile value is zero must be taken with care.

The results on sector level indicate very few significant parameter estimates when export value is used as output (see Appendix 2 for details). But as on aggregated level, the number of export products with a price greater than 1000 SEK per kg seems to be a more proper output measure. According to Table 5.3 local accessibility to university R&D is of importance for the municipalities with few high valued export products (Q10, Q25 and Q50) in the sector "Manufacture of refined petroleum products and chemical products". The number of exported products is, however, zero for Q10 and Q25. The knowledge flows between municipalities within a region (intra-regional) and between regions (inter-regional) are beneficiary in the upper part of the conditional distribution. Local accessibility to company R&D is not proved to have an effect on the number of high valued export products in this sector. The OLS regression indicates significance for this variable, but this is because of a few influential outliers.

Table 5.3: Marginal effects of R&D on number of high valued export products for Swedish municipalities (Equation 2.5). Manufacture of refined petroleum products and chemical products

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	ns	ns	0.332 (2.67)	0.973 (6.43)	0.434 (2.62)
Access to univ R&D, municip	0.007 (2.07)	0.009 (2.47)	0.013 (2.62)	ns	ns	0.010 (3.41)
Access to comp R&D, municip	ns	ns	ns	ns	ns	0.131 (3.72)
Access to comp R&D, intra-reg	ns	ns	0.048 (2.34)	ns	0.189 (3.78)	0.068 (2.37)
Access to comp R&D, inter-reg	ns	ns	ns	0.208 (2.67)	0.290 (3.14)	0.067 (2.26)
Large population (>100 000)	ns	ns	ns	ns	26.28 (2.63)	8.830 (2.35)
Medium population (50 to 100 000)	ns	1.021 (3.11)	1.428 (2.81)	ns	3.716 (2.09)	1.986 (2.56)
Pseudo R^2, Adj R^2	0.272	0.322	0.394	0.539	0.688	0.778
Quantile value, mean value (dependent variable)	0	0	0.667	1.333	6.7	2.720

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

Table 5.4: Marginal effects of R&D on number of high valued export products for Swedish municipalities (Equation 2.5). Manufacture of machinery and equipment

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	0.333 (2.68)	0.896 (3.51)	2.533 (5.20)	5.477 (7.26)	10.61 (8.77)	3.732 (8.58)
Access to univ R&D, municip	ns	ns	ns	ns	ns	ns
Access to comp R&D, municip	ns	ns	ns	ns	5.408 (2.32)	ns
Access to comp R&D, intra-reg	1.328 (1.99)	2.308 (3.11)	2.893 (3.86)	3.937 (3.04)	6.324 (3.47)	3.127 (5.59)
Access to comp R&D, inter-reg	0.544 (3.66)	1.233 (2.31)	2.207 (4.00)	2.794 (3.56)	3.160 (2.90)	2.214 (5.31)
Large population (>100 000)	16.24 (2.43)	16.50 (2.95)	16.20 (2.15)	26.97 (2.63)	ns	21.98 (4.06)
Medium population (50 to 100 000)	8.063 (4.17)	10.60 (4.94)	13.16 (4.27)	13.74 (4.26)	13.24 (3.88)	13.19 (7.77)
Pseudo R^2, Adj R^2	0.202	0.252	0.356	0.452	0.526	0.635
Quantile value, mean value (dependent variable)	0.667	2.667	5.667	13.33	27.47	10.28

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

The regression results of the industrial sector “Manufacture of machinery and equipment” presented in Table 5.4 show very productive intra-regional and inter-regional knowledge flows. The two variables are statistically significant over the whole distribution. Not surprisingly the marginal effects have the largest values in the upper part of the conditional distribution. Local accessibility to company R&D is only important for municipalities with many high valued export products (Q90). Local accessibility to university R&D is of no importance in this sector.

Intra-regional accessibility to company R&D is the variable that best explains the variations of the dependent variable in the third investigated industrial sector “Manufacture of office machinery, electrical machinery and communication equipment” (Table 5.5). Once again the largest marginal effects can be found in the upper part of the distribution. The values are in a range from 0.463 for Q10 to 1.307 for Q90. This is a better way to describe the relationship between the dependent variable and an independent variable, instead of only report the effect at a single point, the conditional mean, as in OLS.

Table 5.5: Marginal effects of R&D on number of high valued export products for Swedish municipalities (Equation 2.5). Manufacture of office machinery, electrical machinery and communication equipment

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	0.314 (2.12)	1.318 (6.65)	3.908 (6.56)	9.144 (6.65)	14.98 (5.15)	6.747 (6.77)
Access to univ R&D, municip	ns	ns	ns	ns	ns	0.019 (2.83)
Access to univ R&D, inter-reg	ns	ns	ns	ns	0.035 (2.25)	ns
Access to comp R&D, municip	ns	ns	ns	ns	ns	0.421 (3.64)
Access to comp R&D, intra-reg	0.463 (4.67)	0.693 (4.44)	0.697 (2.68)	1.155 (3.35)	1.307 (3.87)	0.873 (4.99)
Access to comp R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	96.36 (2.37)	49.39 (3.81)
Medium population (50 to 100 000)	11.43 (3.53)	22.42 (3.82)	29.28 (6.71)	31.97 (3.40)	49.44 (4.67)	30.87 (7.45)
Pseudo R^2, Adj R^2	0.260	0.317	0.418	0.520	0.580	0.717
Quantile value, mean value (dependent variable)	0.667	2.333	7.333	20.17	56.7	18.46

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

Before exploring the importance of human capital on exports, a short sum up might be in order.

- The value of exported products is affected by local accessibility to company R&D. The effects are positive and significant for municipalities with an aggregated export of high values. Knowledge flows between and within functional regions are of no importance.
- The intra- and inter-regional accessibilities play a more important roll for the number of high valued products in Swedish municipalities. This is especially evident when the analysis is conducted on sector level.
- Accessibility to university R&D affects in some occasions the number of high valued products.

5.2 Export and accessibility to human capital (Eq. 2.6)

Estimation results of Equation (2.6) presented in Table 5.6 indicate positive effects of increased local accessibility to human capital. Opposed to R&D (see Table 5.1) well educated people appear to have positive effects also for municipalities with export values in the lower part of the distribution. A local accessibility increase of 10 raises the export value by approximately 5 million SEK (Q10, Q25 and Q50). Furthermore, there are negative impacts of intra-regional accessibility to human capital. This is some what surprising, and the interpretation is that an increased number of well educated people in a municipality have a positive effect on the export value of the municipality but a negative effect on the other municipalities' export values in the region. Another way to put it, municipalities endowed with a lot of human capital are more likely to dominate the region when it comes to exporting capacity measured my total export value. From Table 5.6 it is also evident that there are no beneficial knowledge flows from municipalities outside the own region.

Due to very few significant parameter estimates, the tables presenting the results for the three industrial sectors can be found in Appendix 3 and is not commented upon here.

Table 5.6: Marginal effects of human capital on export value for Swedish municipalities (Equation 2.6). Aggregated data.						
	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	ns	0.222 (2.84)	0.687 (2.17)	2.424 (3.50)	1.011 (4.48)
Access to hum cap R&D, municip	0.0005 (4.80)	0.0005 (4.93)	0.0005 (1.96)	ns	0.0011 (2.71)	0.0005 (5.05)
Access to hum cap R&D, intra-reg	-0.00005 (-2.82)	-0.00004 (-2.94)	ns	ns	-0.0001 (-2.41)	-0.00007 (-2.08)
Access to hum cap R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	ns	3.420 (2.10)
Medium population (50 to 100 000)	ns	ns	ns	3.737 (2.09)	ns	3.765 (2.14)
Pseudo R^2, Adj R^2	0.183	0.236	0.279	0.325	0.391	0.443
Quantile value, mean value (dependent variable)	0.080	0.264	0.720	2.043	4.765	2.236

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

When the number of high valued export products is used as an output, the results are quit different (see Table 5.7).

Table 5.7: Marginal effects of human capital on the number of high valued export products for Swedish municipalities. Aggregated data.						
	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	3.699 (3.04)	5.021 (2.17)	16.68 (3.78)	32.99 (3.62)	12.27 (4.52)
Access to hum cap R&D, municip	0.0074 (2.21)	ns	ns	ns	ns	0.0068 (7.36)
Access to hum cap R&D, intra-reg	0.0014 (2.52)	0.0024 (3.80)	0.0037 (3.53)	0.0043 (3.07)	0.0045 (4.10)	0.0035 (6.45)
Access to hum cap R&D, inter-reg	0.0008 (2.50)	0.0011 (2.38)	0.0032 (2.85)	0.0048 (3.07)	0.0058 (2.39)	0.0032 (3.51)
Large population (>100 000)	83.82 (2.37)	ns	ns	ns	ns	142.4 (4.21)
Medium population (50 to 100 000)	ns	56.74 (3.06)	73.61 (3.27)	69.64 (2.60))	93.04 (2.87)	75.37 (7.68)
Pseudo R^2, Adj R^2	0.358	0.419	0.509	0.616	0.703	0.833
Quantile value, mean value (dependent variable)	5.3	11.67	28.67	66.75	167.4	60.09

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

The local accessibility to human capital seems to matter only for the municipalities having an export value corresponding to Q10. The results also indicate that it is not necessary to have well educated people living in the municipality where the number of high valued export products is registered. Hence, both intra-regional and inter-regional accessibility to human capital have positive and statistically significant parameter estimates over the whole conditional distribution.

The regression results on sector level are presented in Tables 5.8 – 5.10. The local accessibility to human capital in the sector "Manufacture of refined petroleum products and chemical products" has a positive and significant effect for municipalities corresponding to the lower part of the distribution. The interpretations of the marginal effects conditional to Q10 and Q25 must, however, be carefully treated because of feasible censoring problems with the zeroes. In the upper part of the conditional distribution the intra-regional and inter-regional knowledge flows appear to be the dominating variables.

Table 5.8: Marginal effects of human capital on number of high valued export products for Swedish municipalities (Equation 2.6). Manufacture of refined petroleum products and chemical products

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	-0.273 (-3.58)	ns	ns	ns	ns
Access to hum cap R&D, municip	0.0005 (2.27)	0.0008 (5.33)	0.0008 (3.06)	ns	ns	0.0007 (8.77)
Access to hum cap R&D, intra-reg	ns	ns	ns	0.0002 (2.02)	ns	0.0002 (2.64)
Access to hum cap R&D, inter-reg	ns	ns	ns	0.0002 (2.59)	0.0006 (2.79)	ns
Large population (>100 000)	ns	ns	ns	ns	ns	7.093 (1.96)
Medium population (50 to 100 000)	ns	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.175	0.277	0.362	0.482	0.609	0.694
Quantile value, mean value (dependent variable)	0	0	0.667	1.333	6.7	2.720

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

The marginal effects on the number of high valued export products in the sector "Manufacture of machinery and equipment" (Table 5.9) are very similar to the ones on aggregated level (Table 5.7). The dominating variables are intra-regional and inter-regional accessibility to human capital. All OLS parameter estimates are statistically signinficant. But once again these results are not trustworthy since a few very influential observations (municipalities) alone are responsible for the significances.

Table 5.9: Marginal effects of human capital on number of high valued export products for Swedish municipalities (Equation 2.6). Manufacture of machinery and equipment

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	0.601 (2.81)	2.430 (3.85)	3.674 (3.75)	9.037 (4.73)	3.703 (6.54)
Access to hum cap R&D, municip	ns	ns	ns	ns	ns	0.0007 (5.33)
Access to hum cap R&D, intra-reg	0.0002 (2.03)	0.0004 (3.30)	0.0005 (2.88)	0.0005 (2.74)	0.0006 (2.82)	0.0005 (6.63)
Access to hum cap R&D, inter-reg	ns	0.0004 (4.15)	0.0006 (2.33)	0.0011 (4.05)	0.0012 (3.05)	0.0006 (3.13)
Large population (>100 000)	ns	ns	ns	ns	ns	20.24 (2.61)
Medium population (50 to 100 000)	5.486 (2.33)	8.017 (3.38)	11.33 (2.54)	10.34 (1.98)	ns	3.703 (6.54)
Pseudo R^2, Adj R^2	0.254	0.327	0.400	0.498	0.532	0.674
Quantile value, mean value (dependent variable)	0.667	2.667	5.667	13.33	27.47	10.28

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

Table 5.10: Marginal effects of human capital on number of high valued export products for Swedish municipalities (Equation 2.5). Manufacture of office machinery, electrical machinery and communication equipment

	Q10	Q25	Q50	Q75	Q90	OLS,W
(Constant)	ns	ns	1.310 (2.00)	5.393 (3.20)	10.25 (3.55)	3.784 (3.02)
Access to hum cap R&D, municip	0.0021 (2.66)	ns	ns	ns	ns	0.0016 (6.31)
Access to hum cap R&D, intra-reg	0.0004 (2.39)	0.0008 (4.13)	0.0012 (4.08)	0.0016 (3.04)	0.0023 (3.35)	0.0014 (5.02)
Access to hum cap R&D, inter-reg	ns	ns	0.0006 (2.04)	ns	ns	0.0007 (1.98)
Large population (>100 000)	ns	ns	42.99 (2.40)	ns	ns	47.34 (3.55)
Medium population (50 to 100 000)	7.263 (1.98)	20.43 (3.07)	26.58 (3.66)	23.93 (2.16)	46.24 (2.40)	28.11 (6.94)
Pseudo R^2, Adj R^2	0.294	0.364	0.456	0.547	0.587	0.732
Quantile value, mean value (dependent variable)	0.667	2.333	7.333	20.17	56.7	18.46

High valued export products = products with export price > 1000 SEK per kg
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

Table 5.10 shows the marginal effects of accessibility to human capital in the industrial sector "Manufacture of office machinery, electrical machinery and communication equipment" The number of exported products in a municipality is above all affected by the accessibility to well educated people within the region but outside the own municipality. The largest effects can be found for the municipalities with an export performance corresponding to the largest quantiles.

5.3 Human capital or R&D (Eq. 2.7)?

In order to answer the question if it is accessibility to R&D or accessibility to human capital (well educated people) that best explains the variations in municipalities' exports, Equation (2.7) is estimated. The regression results on aggregated level and sector level are presented in Table 5.11.

Table 5.11: Marginal effects on value share of high valued export products for Swedish municipalities (Equation 2.7).

Aggregated data	Q10	Q25	Q50	Q75	Q90	OLS,W
Access to hum cap, municip per 1000 inhabitants	ns	0.055 (2.68)	0.164 (5.24)	0.224 (6.11)	0.356 (2.66)	0.197 (7.68)
Pseudo R^2, Adj R^2	0.022	0.049	0.112	0.177	0.142	0.162
Quantile value, mean value	0.087	0.318	1.480	10.26	29.70	9.544
Machinery and equipment						
Access to hum cap, municip per 1000 inhabitants	0.006 (2.27)	0.016 (4.50)	0.032 (2.66)	0.085 (2.00)	0.355 (2.06)	ns
Access to comp R&D, municip per 1000 employed	3.190 (2.59)	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.013	0.018	0.023	0.026	0.109	0.048
Quantile value, mean value	0.072	0.379	1.414	5.371	15.94	7.142
Office machinery, electrical machinery & communic. eq.						
Access to hum cap, municip per 1000 inhabitants	0.077 (2.70)	0.132 (2.13)	0.384 (3.53)	0.310 (2.30)	ns	0.214 (3.09)
Access to univ R&D, municip per 1000 employed	0.972 (2.52)	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.037	0.056	0.056	0.044	0.013	0.064
Quantile value, mean value	0.371	4.649	24.04	59.69	87.73	34.51

Value share of high valued export products = (value of products with export price > 1000 SEK per kg) / (total export value)
Only statistically significant parameter estimates presented (95% confidence level). T-values in parenthesis.
ns = Not statistically significant (95% confidence level).
N = 288

The table only includes the variables having a statistically significant effect on exports. Consequently, the sector "Manufacture of refined petroleum products and chemical products" is omitted from the table. The results in Table 5.11 indicate a clear dominance for accessibility to human capital on aggregated data and for the three investigated industrial sectors. Thus, having a large share of high valued exported products is primarily determined by accessibility to human capital. Accessibility to company R&D and university R&D are obviously to a large extent crowded out by accessibility to human capital.

6. Conclusions

The purpose in this paper has been to investigate the importance of accessibility to university R&D, company R&D and human capital on exports in Swedish municipalities. Two different output measures have been used, export value and number of export products with a price above 1000 SEK per kg. Although it is hard to separate the effects of the explanatory variables, due to multicolllinearity problems, the empirical findings indicate that accessibility to human capital is the factor that drives the export performance the most. Both accessibility to company R&D and accessibility to human capital affects exports separately so it could be worth while investigating this aspect further. Perhaps the problem could be solved by structural equation modeling (SEM), factor analysis (which is incorporated in SEM) or ridge regression, but this is left for future research. Accessibilty to university R&D seems to have very little impact on exports.

How about the importance of geographical proximity? The effects are very local when total export value in municipalities is the dependent variable in the knowledge production function. Local (within the municipality) accessibility to human capital (or company R&D) is the only variable that has a positive statistically significant effect on aggregated data. The intra-regional and inter-regional knowledge flows appear to be more influential when the output measure is the number of high value export products.

All estimations are conducted with quantile regression. The paper emphasizes the appropriateness of this regression technique, especially when the dependent variable has influential outliers and the distribution is skewed. But also in general, when the research unit is heterogeneous with respect to the explanatory variables and an investigation performed over the whole conditional distribution is needed.

References

Acs, Z.J., Anselin, L., & Varga, A. (2002), Patents and Innovation Counts as Measures of Regional Production of New Knowledge, *Research-Policy* 31, 1069-85

Acs, Z.J. & Audretsch, D.B., (1989), Patents as a Measure of Innovative Activity, *Kyklos, Blackwell Publishing*, vol. 42(2), pages 171-80

Anselin L., Varga A., & Acs Z., (1997), Local Geographic Spillovers Between University Research and High Technology Innovations, *Journal of Urban Economics* 42, 422-448

Audretsch, D.B., Feldman, M.P (1996), R&D spillovers and the geography of innovation and production, *American Economic Review* 86 (3), 630–640

Audretsch D. B., Lehman E. E. & Warning S., (2004), University spillovers and new firm location, *Discussion papers on entrepreneurship, growth and public policy* 2004-02, Max Planck Institute, Jena, Germany

Beckman, M. (2000), Interurban Knowledge Networks, in Batten, D. et al (eds) (2000), *Learning, Innovation and the Urban Evolution*, Kluwer Academic Publishers, London

Buchinsky, M. (1998), Recent Advances in Quantile Regression Models: A Practical Guideline for Empirical Research, *Journal of Human Resources* 33(1):88-126.

Cameron, C. & Trivedi P. K. (2001), Essentials of Count Data Regression, in *Badi H. Baltagi ed., A Companion to Theoretical Econometrics, 2001*, pp. 331-348, Blackwell, Oxford (U.K.)

Chernozhukov, V. V. & Umantsev, L., (2001), Conditional Value-at-Risk: Aspects of Modeling and Estimation, *Empirical Economics*, 26, 271–292

Eide, E. & Showalter, M. H., (1998), The Effect of School Quality of Student Performance: A Quantile Regression Approach, *Economics Letters*, 58, 345–350

Feldman, M. P. & Florida, R. (1994), The geographic sources of innovation: Technological infrastructure and product innovation in the United States, *Annals of the Association of American Geographers* 84, 210–229.

Feldman, M. (2000), Location and Innovation: The New Economic Geography of Innovation, Spillovers, and Agglomeration, *The Oxford Handbook of Economic Geography. Oxford University Press*

Florida. R. & Lee S.Y., (2001), Innovation, Human Capital, and Diversity, *Conference paper* Prepared for the APPAM 2001 Conference, November 1, 2001, Washington DC.

Griliches, Z., (1979), Issues in Assessing the Contribution of R&D to Productivity Growth, *Bell Journal of Economics* 10, 92-116

Gråsjö U., (2004), The Importance of Accessibility to R&D on Patent Production in Swedish Municipalities, *Working Paper Series in Economics and Institutions of Innovation 19*, Royal Institute of Technology, CESIS

Gemmel, N. (1996), Evaluating the Impacts of Human Capital Stocks and Accumultion on Economic Growth: Some New Evidence, *Oxford Bulletin of Economics and Statistics*, Vol. 58. 1

Glaeser, E., Scheinkman, J.D. and Shleifer, A. (1995), Economic Growth in a Cross-Section of Cities, *Journal of Monetary Economics* 36

Gould, W. W. (1992), Quantile regression with bootstrapped standard errors. *Stata Technical Bulletin* 9: 19–21

Jacobs, J. (1961), The Death and Life of Great American Cities.

Jaffe, A.B., (1989), Real effects of academic research, *American Economic Review* 79, 957–970

Jaffe, A.B., Trajtenberg, M., Henderson, R. (1993), Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics* 108, 577–598

Johansson, B. & Klaesson, J. (2001), Förhandsanalys av Förändringar i Transport- och Bebyggelsesystem, JIBS

Johansson, B., Klaesson, J., & Olsson M. (2003), Commuters' Non-Linear Response to Time Distances, *Journal of Geographical Systems*

Karlsson, C. & Manduchi, A. (2001), Knowledge Spillovers in a Spatial Context., *in Fischer, M. & Fröhlich, J. (2001), Knowledge, Complexity and Innovation Systems*, Springer-Verlag, Berlin

Koenker, R. & Bassett G. (1978), Regression Quantiles, *Econometrica,* 46(1), 33–50.

Koenker, R. & Bassett G. (1982), Robust tests for heteroscedasticity based on regression quantiles, *Econometrica* 50: 43–61

Lucas, R. (1988), On the Mechanics of Economic Development, *Journal of Monetary Economics 22*

Powell, J. L. (1984), Least Absolute Deviation Estimation for the Censored Regression Model, *Journal of Econometrics*, 25, 303–325

Powell, J. L. (1986), Censored Regression Quantiles, *Journal of Econometrics*, 32, 143–155

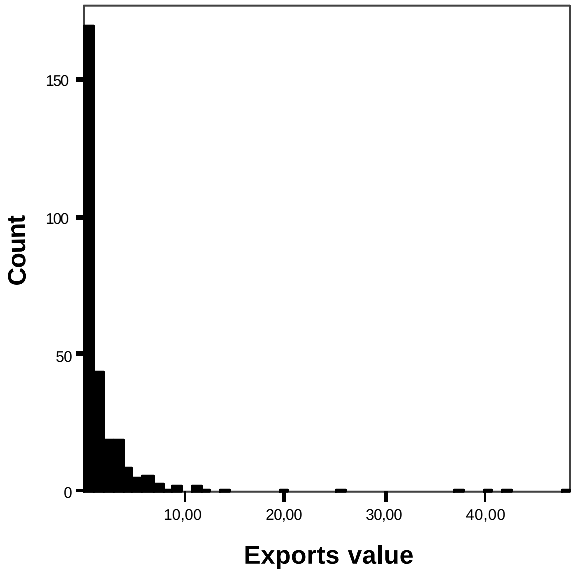
Rogers, W. H. (1992), Quantile regression standard errors. *Stata Technical Bulletin* 9: 16–19

Rogers, W. H. (1993), Calculation of quantile regression standard errors. *Stata Technical Bulletin* 13: 18–19

Simon, C. (1998), Human Capital and Metropolitan Employment Growth, *Journal of Urban Economics* Vol.43

Weibull, J., (1976), An Axiomatic Approach to the Measurement of Accessibility, *Regional Science and Urban Economics*, 6, 357-379

Appendix 1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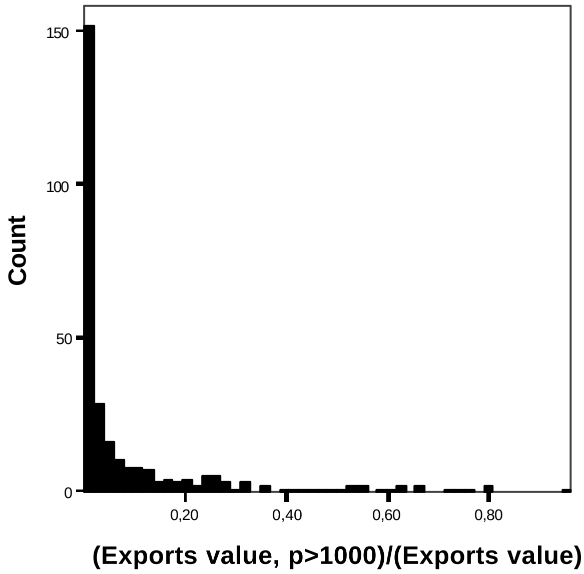
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0,20
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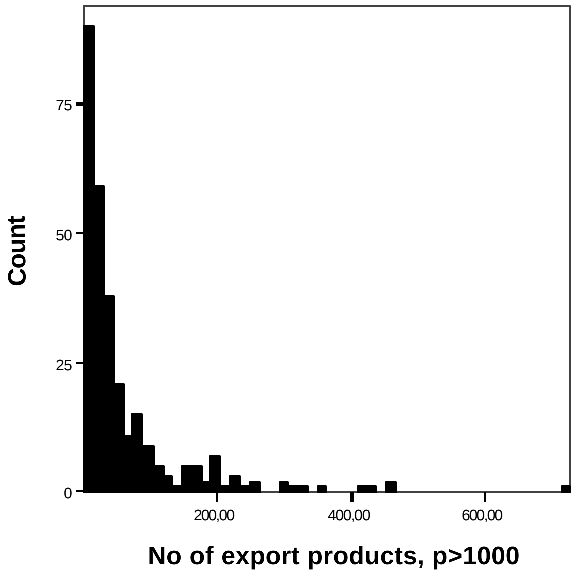
0,80
(Exports value, p>1000)/(Exports value)


Count
75
50
25
0
200,00
400,00
600,00
No of export products, p>1000

Appendix 2

In the table below the sensitiveness of OLS from outliers is demonstrated. The first column shows the estimation of the full sample. If the eight largest observations of the dependent variable are deleted the parameter estimate of local accessibility to university R&D is still significant. But when the nine largest observations are deled, the estimate becomes insignificant. Note also the drop in R^2.

OLS results on number of high valued export products			
	N=288	N=280	N=279
(Constant)	19.27 (8.48)	20.46 (9.74)	26.61 (9.80)
Access to univ R&D, municip	**0.046** **(2.48)**	**0.047** **(2.90)**	**0.0005** **(0.04)**
Access to univ R&D, inter-reg	0.080 (3.31)	0.080 (3.29)	0.078 (3.22)
Access to comp R&D, municip	0.520 (4.80)	0.440 (4.48)	0.394 (5.02)
Access to comp R&D, intra-reg	0.517 (6.75)	0.439 (7.05)	0.449 (7.04)
Large population (>100 000)	161.7 (4.75)	115.1 (10.0)	126.9 (12.2)
Medium population (50 to 100 000)	80.76 (8.14)	75.07 (7.45)	76.59 (7.53)
Adj R^2	0.815	0.701	0.684

Appendix 3

Marginal effects of R&D on exports value for Swedish Municipalities (Equation 2.5). Sector level						
Refined petroleum products and chemical products	Q10	Q25	Q50	Q75	Q90	OLS,W
Access to univ R&D, municip	ns	ns	ns	ns	ns	ns
Access to comp R&D, municip	ns	ns	ns	0.097 (2.10)	ns	ns
Access to comp R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to comp R&D, inter-reg	ns	ns	ns	ns	0.014 (2.01)	ns
Large population (>100 000)	ns	ns	ns	ns	2.913 (2.12)	ns
Medium population (50 to 100 000)	ns	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.047	0.054	0.181	0.492	0.687	0.476
Quantile value, mean value	0.00002	0.0002	0.0044	0.0308	0.3392	0.2441
Machinery and equipment						
Access to univ R&D, municip	ns	ns	ns	ns	ns	ns
Access to comp R&D, municip	ns	ns	ns	ns	ns	ns
Access to comp R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to comp R&D, inter-reg	ns	ns	ns	ns	0.118 (2.20)	ns
Large population (>100 000)	ns	0.997 (2.22)	0.939 (2.49)	0.811 (2.00)	ns	0.817 (2.25)
Medium population (50 to 100 000)	ns	0.130 (2.58)	ns	ns	0.994 (3.31)	0.401 (3.13)
Pseudo R^2, Adj R^2	0.076	0.099	0.185	0.335	0.426	0.350
Quantile value, mean value	0.0018	0.0106	0.0604	0.2119	0.9164	0.3076
Office machinery, electrical machinery & communic. eq.						
Access to univ R&D, municip	ns	ns	ns	ns	ns	ns
Access to univ R&D, inter-reg	ns	ns	ns	ns	ns	ns
Access to comp R&D, municip	ns	ns	0.064 (2.18)	ns	ns	0.062 (11.2)
Access to comp R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to comp R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	ns	ns
Medium population (50 to 100 000)	ns	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.122	0.127	0.179	0.229	0.249	0.097
Quantile value, mean value	0.0001	0.0010	0.0078	0.0789	0.3749	0.4420

Marginal effects of human capital on exports value for Swedish Municipalities (Equation 2.6). Sector level						
Refined petroleum products and chemical products	Q10	Q25	Q50	Q75	Q90	OLS,W
Access to hum cap R&D, municip	ns	ns	ns	ns	ns	0.0001 (10.88)
Access to hum cap R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to hum cap R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	ns	ns
Medium population (50 to 100 000)	ns	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.0089	0.0313	0.1315	0.2661	0.3546	0.2779
Quantile value, mean value	0.00002	0.0002	0.0044	0.0308	0.3392	0.2441
Machinery and equipment						
Access to hum cap R&D, municip	ns	ns	ns	0.0002 (2.19)	0.0002 (2.37)	ns
Access to hum cap R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to hum cap R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	ns	ns
Medium population (50 to 100 000)	ns	ns	ns	ns	0.784 (2.01)	ns
Pseudo R^2, Adj R^2	0.0367	0.1139	0.1828	0.2873	0.3896	0.3405
Quantile value, mean value	0.0018	0.0106	0.0604	0.2119	0.9164	0.3076
Office machinery, electrical machinery & communic. eq.						
Access to hum cap R&D, municip	ns	ns	ns	0.0002 (3.11)	ns	0.0002 (8.12)
Access to hum cap R&D, intra-reg	ns	ns	ns	ns	ns	ns
Access to hum cap R&D, inter-reg	ns	ns	ns	ns	ns	ns
Large population (>100 000)	ns	ns	ns	ns	ns	-1.114 (-2.22)
Medium population (50 to 100 000)	ns	ns	ns	ns	ns	ns
Pseudo R^2, Adj R^2	0.0129	0.0278	0.0954	0.1832	0.2237	0.0975
Quantile value, mean value	0.0001	0.0010	0.0078	0.0789	0.3749	0.4420

Appendix 4

Description and statistics of the industrial sectors

Group	Export value per year, bSEK (1997-1999)	No. of export products with price > 1000 SEK/kg (1997-1999)	Description	SNI codes
G1	3.60	54	Agriculture, forestry and fishing	1, 2, 5
G2	5.95	14	Mining	10, 11, 12, 13, 14
G3	14.45	55.67	Manufacture of food and tobacco products	15, 16
G4	11.36	1045.33	Manufacture of textiles, clothing an leather products	17, 18, 19
G5	24.59	33.67	Manufacture of wood and wood products, except furniture	20
G6	68.49	432.67	Manufacture of paper, paper products, publishing and printing	21, 22
G7	70.30	783.33	Manufacture of coke, refined petroleum products and nuclear fuel, chemicals and chemical products	23, 24
G8	16.45	389.33	Manufacture of rubber and plastics products	25
G9	6.16	255	Manufacture of other non-metallic mineral products	26
G10	44.41	296	Manufacture of basic metals	27
G11	20.85	1010.67	Manufacture of fabricated metal products, except machinery and equipment	28
G12	88.60	2961	Manufacture of machines and equipment	29
G13	127.29	5315.33	Manufacture of office machinery, electrical machinery and communication equipment	30, 31, 32
G14	18.82	3550.33	Manufacture of medical, precision and optical instruments, watches and clocks	33
G15	106.49	417	Manufacture of motor vehicles and other transport equipment	34, 35
G16	13.69	563.67	Manufacture of furniture	36
G18	2.20	3	Distribution of water and electricity	40
G27	0.06	71.33	Other business activities	74
G30	0.24	58.33	Other community, social and personal service activities	90, 91, 92, 93
Tot	643.99	17309.67		