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By

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Abstract

Knowledge is maintained as a core variable for growth in a large set of contemporary theories. In this paper, we analyze the relationship between knowledge accessibility and regional growth. The knowledge resource used in our model R&D conducted at universities and in companies. A precise definition of accessibility was introduced and calculations were based on actual travel time distances. Using data at the municipality level in Sweden, the hypothesis that knowledge accessibility has a positive effect on growth cannot be rejected. The knowledge accessibility in a given period has a statistically significant effect on the growth in value-added per employee in subsequent periods.

The total accessibility of a municipality was divided into three types, (i) intra-municipal accessibility, (ii) intra-regional accessibility and (iii) extra-regional accessibility. The paper has shown that this division gives a clear indication of that there is spatial dependence in the sense that the knowledge resources in a given municipality tend to have a positive effect on the growth of another municipality, conditional on that the municipalities belongs to the same functional region. Thus, the results of the analysis indicate that knowledge flows transcend municipal borders, but that they tend to be bounded within functional regions.

The findings in the paper provide support for the theories that emphasize the role of knowledge for growth. However, the paper demonstrates that spatial proximity to knowledge resources is important to materialize the positive effect of such resources. Accessibility to knowledge in space is thus imperative.

Key-words: knowledge, R&D, economic growth, accessibility, spatial, region, spillovers

JEL-codes: R110, O520, O300, O400

1. Introduction

Paul Krugman has argued many times that a most fundamental aspect of economic activities is that they tend to cluster in space. However, the tendency to cluster is stronger for certain types of activities than for others. One type of economic activity with a very strong tendency to cluster is R&D. This is a general trait of all economies but many economists still seems to neglect this fact. Too many still, for example, analyse the role of R&D for economic growth using aggregated models for the whole national economy. However, the fact that R&D is spatially concentrated ought to be acknowledged, since it is well established that knowledge flows are bounded in space. The general tendency of R&D activities to cluster can be explained by the existence of increasing returns, which make R&D activities more productive and more profitable when they agglomerate. The existence of increasing returns signal that that market forces might be unable to generate an optimal resource allocation, since individual actors do not take into account the effect of their own actions on the operations of other actors.

Given the general assumption that R&D-generated knowledge contributes to economic growth it is of great importance to understand how R&D contributes to economic growth in an economy where R&D is strongly concentrated to a limited number of regions. Such an understanding is contingent upon an understanding of the character of knowledge and knowledge flows. There are strong evidences that knowledge transfers to a high extent are dependent upon face-to-face interaction. The volume of knowledge flows depends upon the interaction possibilities at different spatial scales. We assume that is meaningful to identify a number of such spatial scales based upon the character of the generalised spatial interaction costs. In particular, we claim that there are three spatial scales that are of special importance: (i) The local scale that allows several interactions per day, (ii) The intra-regional scale – the commuting scale – that allows for daily interaction, and (iii) The inter-regional scale that only allows for a limited number of planned interactions per month or year.

We have for several years argued that the interaction possibilities at the different spatial scales can be properly represented by an accessibility approach, which discounts the interaction potentials using travel time distances and time sensitivity parameters, which are different for different spatial scales. By this approach it is possible to highlight the knowledge potential of each spatial unit with proper consideration of the fact that the more distant a knowledge source the less it contributes to the knowledge potential in a given location. Having defined the knowledge potential of each spatial unit it is possible to estimate the contribution of knowledge to the economic growth of the different spatial units that makes up the national economy. Having established such a relationship it is also possible to estimate the effects on economic growth of increases in R&D investments and investments in transport infrastructure reducing travel times as well as alternative allocations of existing R&D investments. These issues are of great interest to both national and regional governments interested in stimulating economic growth.

Against this background the purpose of the current paper is to analyse the contribution of R&D to economic growth in Swedish municipalities taking proper account of the variation in R&D accessibility between different municipalities.

The paper is organised as follows: In Chapter 2 we present our theoretical framework, explain the accessibility concept and how we operationalise it, and present our hypotheses. Our empirical model, our data, our estimation techniques, and our regression results are presented in Section 3. Section 4 concludes.

2. Knowledge Accessibility and Economic Growth

A limiting factor with the traditional endogenous growth approaches is the assumption of general accessibility of the stock of knowledge across space. If knowledge is not easily accessible at every point in space, the location of knowledge production and the characteristics of knowledge flows become critical issues in understanding economic growth. However, there are strong reasons to believe that the stock of knowledge is not evenly accessible across countries or even across functional regions within countries.

New knowledge is often extremely complicated and contains complex (and sometimes tacit) elements which imply that it often only is accessible via interactions within either inter-firm innovation networks or general innovation systems that tend to be bounded by geographical proximity (Karlsson, 1997; Karlsson and Manduchi, 2001; Andersson and Karlsson, 2004 & 2006). Strong evidence is also provided for both the US and Europe that knowledge flows measured by patent citations are bounded within a relatively narrow geographical range (Jaffe, Trajtenberg & Henderson, 1993; Almeida & Kogut, 1999; Maurseth & Verspagen, 1998; Verspagen & Schoenmakers, 2000). Of particular concern is also the volume of human capital engaged in the generation of new ideas, innovations and technologies in different locations.

The implications of these factors are far-reaching. Functional urban regions[2] will differ not only in terms of their production of and access to knowledge but the mix of knowledge will also be different between functional regions. Thus, important elements of the production of knowledge will tend to be regional rather than national. This will probably have its strongest effects on science-based and high-technology industries but will in principle influence all industries to the extent they innovate. Empirical analyses also show that the production of new scientific and technological knowledge has a predominant tendency to cluster spatially (Varga, 1999; Caniëls, 2000). Sensitivity of the transmission of new knowledge to distance seems to provide a principal reason for the development of regional innovation clusters (Acs, Anselin & Varga, 2002). Hence, it is natural that in the regional development literature, the geographical distribution of knowledge workers is hypothesized to be a key driver of existing and future patterns of regional growth (Nijkamp & Poot, 1998; Bal & Nijkamp, 1998; Mathur, 1999; Florida, 2000 & 2002). This implies that the kinds of work the regional economy does deserve at least as much attention as the kinds of products it makes (Thompson & Thompson, 1985 & 1987; Feser, 2003).

Recently, some economists have suggested an important link between national economic growth and the concentration of people and firms in large urban regions. The high

[2] Functional urban regions are delimited by labour and housing market perimeters.

concentration of people and firms in large urban regions creates an environment in which knowledge move quickly from person to person and from firm to firm. This implies that large, dense locations encourage knowledge flows and knowledge exchange, thus facilitating the spread of new knowledge that underlies the creation of new or improved goods and new ways of producing existing goods (Carlino, 2001). Glaeser, et al. (1992) shows that localized inter-industry knowledge flows can explain the economic growth of US cities. Cheshire & Carbonaro (1995) presents an analysis in a regional context, which embodies increasing returns to human capital as a result of spillovers which occur due to the non-rival and partially non-excludable component of knowledge generation. They model the rate of growth of non-rival knowledge as a function of the total human capital that is employed in research multiplied with the stock of knowledge, allowing for the differential concentration of human capital among regions. Moreover, Fujita & Thisse (2003) show theoretically that the growth of the global economy depends on the spatial organization of the innovation sector across regions.

Given these considerations, it is apparent that there is a need for a modeling approach that can mirror existing variations within and between functional urban regions in terms of knowledge generation and conditions for local, intra- and inter-regional knowledge flows. Knowledge flows are related to the mobility and interaction of people. Thus, spatial proximity is generally assumed to be instrumental in facilitating knowledge flows among actors[3]. Given that mobility and interaction is time-consuming it is natural that mobility and interaction varies between different geographical scales, such as the local, the intra-regional and the inter-regional scale.

Against this background, Karlsson & Manduchi (2001) have suggested the use of accessibility measures to make the role of mobility and interaction patterns in knowledge production functions operational. What are then the benefits of accessibility measures?

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[3] In this context, a common apprehension is that the most recent, and as such the most valuable type of knowledge, tends to have such a complex, uncertain and non-codified form that it can not be fully articulated and may only be transferred through personal interactions (Polanyi, 1996; Dosi, 1988; Feldman, 1994)

Weibull (1980, 54) maintains that accessibility measures can be seen as measures of (i) nearness, (ii) proximity, (iii) ease of spatial interaction, (iv) potential of opportunities of interaction, and (v) potentiality of contacts with activities or suppliers.

By using accessibility measures, proximity is discounted in a way that reflects the propensity of economic actors with different locations to travel to different destinations inside and outside regions at given travel times. Moreover, accessibility calculations are based on actual travel time distances within and between different regions. This implies that the effects of improved passenger transport infrastructure and/or changed localization patterns can be estimated.

2.1 Accessibility Explained

The starting point for a distinction between different types of accessibility is that a national economy can be divided into functional urban regions that consist of one or several localities. In this paper, such localities are labeled municipalities. Functional urban regions are connected to other functional regions by means of economic and infrastructure networks. The same prevails for the different localities (or municipalities) within a functional urban region. Moreover, each municipality can also be looked upon as a number of nodes connected by the same type of networks. The borders between functional urban regions are characterized by a decline in the intensity of economic interaction including commuting compared to the intraregional interaction. Thus, functional urban regions can be approximated with labor market regions.

With reference to such a structure, it is possible to define three different spatial levels or scales with different characteristics in terms of mobility and interaction opportunities. Because of this, it is also possible to construct three different categories of accessibility. Johansson, Klaesson & Olsson (2002) separates between: (i) intra-municipal or local accessibility, (ii) intra-regional accessibility and (iii) extra- or inter-regional accessibility. Based on commuting data, they also show that the time sensitivity parameter λ is different for intra-municipal, intra-regional and extra-regional interaction. Inside a municipality, parameter λ^1 applies, inside the pertinent region parameter λ^2 applies and for contacts outside the region parameter λ^3 applies. These differ in size in the following way: $\lambda^2 > \lambda^3 > \lambda^1$.

In order to explain the three different accessibility measures in more detail, one has to start at the municipality level. The focus is on municipality s in a functional urban region R, so that $s \in R$. The average time distance between zones in municipality s is denoted by t_{ss} and the size of the opportunity D in the same municipality is given by D_s. From this, the intra-municipal accessibility to the opportunity D_s is calculated as follows:

$$A_{sM}^{D} = \exp\{-\lambda^1 t_{ss}\} D_s \qquad \textbf{(2.1)}$$

However, the economic actors in municipality s have also accessibility to the opportunity D in all other municipalities r that belong to region R. By letting t_{sr} denote the time distance between municipality s and r the intra-regional accessibility of municipality s can be expressed as:

$$A_{sR}^{D} = \sum_{r \in R,\ r \neq s} \exp\{-\lambda^2 t_{sr}\} D_r \qquad \textbf{(2.2)}$$

Finally, economic actors such as firms and households in municipality s also have accessibility to the opportunity D_k in the k municipalities outside region R. This extra- or inter-regional accessibility is specified in formula (2.3)**:**

$$A_{sE}^{D} = \sum_{k \notin R} \exp\{-\lambda^3 t_{sk}\} D_k \qquad \textbf{(2.3)}$$

D_i is here a measure of opportunities in each municipality and can relate to opportunities such as suppliers, customers, supply of producer services, supply of educated labor, universities and R&D institutes, R&D activities, higher education, patents, etc. (see, inter alia, Klaesson, 2001). The accessibility measure of the type that discussed here satisfies certain criteria of consistency and meaningfulness, (see e.g. Weibull, 1976).

2.2 Knowledge Accessibility and Economic Growth

In this section, we present a simple model of growth in output per worker, which incorporates knowledge accessibility in a simple fashion. We assume that each municipality s has an aggregate production function in which the technological progress is *labor-augmenting* or *Harrod-neutral*:

$$Y_s = K_s^{\alpha}\left(A_s L_s\right)^{1-\alpha} \tag{2.4}$$

In Equation (2.4), A_sL_s is effective labor, i.e. labor supply L_s times the total knowledge accessibility A_s. Writing Equation (2.4) in terms of labor gives us:

$$y_s = k_s^{\alpha} A_s^{1-\alpha} \tag{2.5}$$

By taking logs and differentiating, the change in output per labor in region s, Δy_s, can be expressed as:

$$\Delta y_s = \alpha \frac{\Delta k_s}{k_s} y_s + (1-\alpha)\frac{\Delta A_s}{A_s} y_s \tag{2.6}$$

Over a period of 6-7 years, it can be assumed that the change in capital intensity (i.e. capital per worker) is close to zero, $\Delta k_s \approx 0$. This simplification implies that the change in output per worker is solely a function of the technological progress, as shown in Equation (2.7):

$$\Delta y_s = (1-\alpha)\frac{\Delta A_s}{A_s} y_s \tag{2.7}$$

The technological knowledge accessibility in a municipality is assumed to evolve according to:

$$\Delta A_s = \delta_s A_s \left(\frac{A_s}{y_s}\right) \tag{2.8}$$

where δ_s is parameter representing the productivity of the knowledge creating activities. In equation (2.8) this productivity parameter is expressed as a function of the human capital in municipality s, $\delta_s = f(h_s)$, measured with e.g. the quality of the municipal workforce in terms of education. This formulation rests on the assumption that the absorptive capacity (c.f. Cohen & Levinthal, 1990) of the economic actors in a municipality increases with the workforce's level of education. Thus, educated workers are expected to be better at exploiting the knowledge stock than non-educated workers[4]. Moreover, Equation (2.8) implies that not only the size of the knowledge accessibility matters but also its size in relation to output per worker. Substitution of (2.8) into (2.7) gives us:

$$\Delta y_s = (1-\alpha)\delta_s A_s \tag{2.9}$$

The knowledge accessibility A_s in municipality s is defined in accordance with the discussion in Section 2.1,

$$A_s \equiv \sum_{W=1}^{k} A_s^W = \sum_{W=1}^{k} (\beta_{1w} A_{sM}^W + \beta_{2w} A_{sR}^W + \beta_{3w} A_{sE}^W) \tag{2.10}$$

[4] See Fagerberg, Verspagen & Caniëls (1997) for strong empirical support for the role of absorptive capacity. They find that some level of R&D in a region is necessary to absorb the knowledge developed in other regions.

where W stands for different kinds of knowledge resources (opportunities in Section 2.1) and the β's represent the relative importance of each type of knowledge accessibility. Equation (2.9) and (2.10) leaves us with the following equation to be estimated:

$$\Delta y_s = \varphi + \sum_{W=1}^{k} (\theta_{1W} \delta_s A_{sM}^W + \theta_{2W} \delta_s A_{sR}^W + \theta_{3W} \delta_s A_{sE}^W) + \varepsilon_s$$

$$\theta_{iw} \equiv \beta_{iw} (1 - \alpha) \tag{2.11}$$

Equation (2.11) will be estimated across Swedish municipalities. The distinction between the three types of accessibilities in (2.11) makes it possible to estimates the influence from each type. This gives important information about the nature of knowledge flows, i.e. do they cross municipal borders? As stated previously, a main assumption in the paper is that the potential for interaction at various spatial scales transforms into potential knowledge flows. What is meant by knowledge flows? Here, the term is used as a comprehensive term for different types of flows of knowledge. Figure 2.1, adapted from Johansson (2005, provides a general classification scheme of such flows.

Firstly, knowledge flows can be purely transaction-based. In this case, there is an explicit agreement of transaction of knowledge between the parties involved. Such transactions can either be subject to monetary payments of knowledge or be constituted by R&D cooperation in which case the parties share losses and profits in some pre-specified fashion, (cf. Johansson, 2005). Secondly, knowledge may flow in the form of knowledge spillovers, i.e. unintended side effects of ordinary activities. Such spillovers can in turn be divided into (i) spillovers mediated by market mechanisms and (ii) spillovers as pure externalities. Hence, in terms of the characteristics (i) is equivalent to pecuniary externalities and (ii) to technological externalities. Market-mediated knowledge spillovers occur for example via the labor market and as a by-product of purchasing and selling goods as when a seller gains knowledge from a standard transaction with a customer. Knowledge spillovers as pure externalities occur for example when firms observe certain routines and techniques and copy or imitate each other. The model in

Equation (2.11), however, does not distinguish between the different types of knowledge flows.

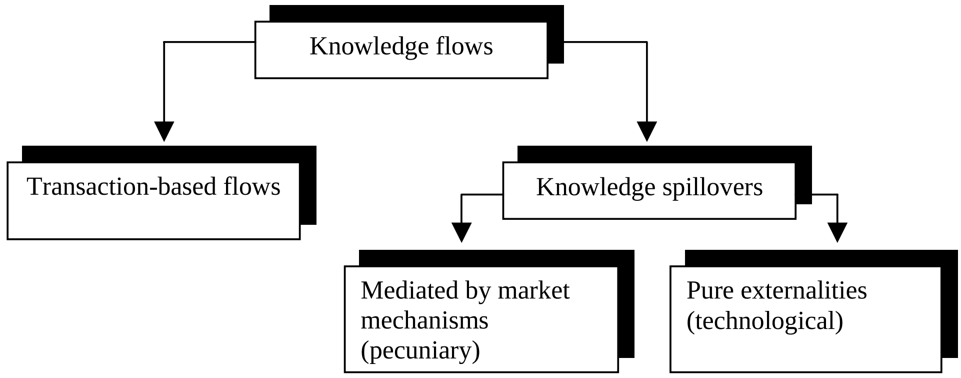

Figure 2.1 Classification of knowledge flows.

2.3 Hypotheses to Be Tested Empirically

The model in Equation (2.11) above will in the next section be tested empirically using data for Swedish municipalities. In Sweden there are two major performers: private companies and universities. Together they account for about x % of all R&D in Sweden. This implies that the rest of the public sector and R&D institutes play a very limited role indeed in Swedish R&D.

Given that there are two major sources of R&D Equation (2.11) will contain six different types of R&D accessibility: local, intra-regional, and inter-regional accessibility to company and university R&D, respectively. Our first hypothesis is that the larger the R&D accessibilities, the larger the rate of growth. Our second hypothesis is that local R&D accessibilities will exert the strongest effects and inter-regional accessibilities the weakest effect with the effects of intra-regional accessibilities in between. Concerning the relative importance of company and university R&D, we expect the former to have a stronger influence since its volume is substantially higher than the latter.

We have also reason to believe that the accessibility to R&D do not affect growth homogenously across municipalities. Therefore, besides using the full sample in the regressions, the 286 municipalities are dived into three categories. First, the largest municipality in all the 81 local labour market regions (LLMRs) represent one group as central places of the highest rank in their respective regions.[5] Second, other municipalities in the four largest labour market regions make up the second group. This group contains 61 municipalities. Third, other municipalities in small labour market regions make up the third group. This group consists of 144 municipalities. Our hypothesis is that we find the largest effects in the first two groups.

3. An Empirical Analysis of Knowledge Accessibility and Economic Growth

3.1 Empirical model, data and estimation teqniques

The empirical model to be estimated is presented in Equation (3.1). Besides the accessibility variables, it also includes some control variables.

$$\begin{aligned}\Delta y_s &= \varphi + \theta_1(\omega_s A_{sM}^{CRD}) + \theta_2(\omega_s A_{sR}^{CRD}) + \theta_3(\omega_s A_{sE}^{CRD}) + \\ &+ \theta_4(\omega_s A_{sM}^{URD}) + \theta_5(\omega_s A_{sR}^{URD}) + \theta_6(\omega_s A_{sE}^{URD}) + \\ &+ \theta_6 E_s + \theta_8 D_s^{mig(+)} + \theta_9 D_s^{pop1} + \theta_{10} D_s^{pop2} + \varepsilon_s\end{aligned} \tag{3.1}$$

[5] Local labour market regions in most cases consist of several and in the three metropolitan regions many municipalities connected through intensive commuting flows. In the sparsely populated areas in Sweden these regions are often made up by single municipalities. These regions are good approximations of functional regions.

Table 3.1 explains and provides a description of the variables in Equation (3.1).

Table 3.1 Description of the variables in Equation (3.1)

Variable	**Description**
Δy_s	Change in value-added per employee in municipality *s* 1993-2001.
ω_s	Knowledge intensity of the workforce in municipality *s*.[6]
A_{sM}^{URD}	Intra-municipal accessibility to university R&D in municipality *s*.
A_{sR}^{URD}	Intra-regional accessibility to university R&D in municipality *s*.
A_{sE}^{URD}	Extra-regional accessibility to university R&D in municipality *s*.
A_{sM}^{FRD}	Intra-municipal accessibility to company R&D in municipality *s*.
A_{sR}^{FRD}	Intra-regional accessibility to company R&D in municipality *s*.
A_{sE}^{FRD}	Extra-regional accessibility to company R&D in municipality *s*.
E_s	Number of 1-person companies in municipality *s* normalised by employment (in 10 thousands) in municipality *s*.
$D_s^{mig(+)}$	Dummy which takes the value 1 if municipality s experienced positive net migration1993-2001, 0 otherwise.
D_{s1}^{pop}	Dummy which takes the value 1 if municipality s have a population > 100 000, 0 otherwise.
D_{s2}^{pop}	Dummy which takes the value 1 if municipality s have a population between 50 000 and 100 000, 0 otherwise.

Municipal growth is measured as the absolute change in value-added per employee in nominal prices.[7] The data on value-added, i.e. gross municipal product (GMP) comes from Statistics Sweden (SCB) and consists of the sum of wages and gross profits. The R&D data originates from SCB. These data are collected by SCB via questionnaires that are sent out to companies and universities. The R&D data is measured in man-years. One

[6] The knowledge intensity is calculated as $\omega_s = \eta_s /(1-\eta_s)$, where η_s denotes the share of the employees in municipality s with a university education of at least three years.

[7] There are no regional price indicies in Sweden. Using the same natural price index for all municipalities does not add any variation between municipalities.

man-year is the amount of work a full time employee performs during a year. This means that a full-time employee who only spends 50% of her work on R&D counts as 0.5 man-years. The accessibility calculations are based on a Swedish travel time-distance matrix, which gives the minimum travel time by car between zones within municipalities and between municipalities. This matrix is provided by the Swedish Road Administration (SRA). As described in Section 2.1, three different values of the time-distance sensitivity parameter, λ, are used: (i) 0.02 for intra-municipal accessibility, (ii) 0.1 for intra-regional accessibility and (iii) 0.05 for extra-regional accessibility. These values found by Johansson, Klaesson & Olsson (2003), who estimated the value of the respective λ by using Swedish commuting data. Following the discussion in Section 2.2, all the accessibility variables are weighted by the knowledge intensity of the municipality's workforce, ω_s. Hence ω_s is used as a proxy for $\delta_s = f(h_s)$ in Section 2.2. This means that the accessibility to knowledge (R&D) is assumed to have a larger effect if the level of the municipality's workforce is large.

It is suggested in the literature that entrepreneurship spurs growth. As seen in Table 3.1, entrepreneurship is proxied by the number of 1-persons companies. Although this is s crude proxy, it is frequently used in the literature (see e.g. Braunerhjelm & Borgman, 2004). The model specification in (3.1) also includes a dummy for whether the municipality has had a positive net migration under the period of investigation. 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_{s1}^{pop}), medium sized (Ds_{2}^{pop}) and a small population. The hypothesis is that municipalities with large populations have an economic activity, such as business services, competitors, suppliers, buyers etc., that exceeds smaller municipalities' and this ought to affect growth.

In Appendix some descriptive statistics of the variables in the empirical analysis are presented. Inspection of the figures reveals that the minimum value for all intra-regional accessibilities is zero. This is due to that some regions only consist of one municipality, in which case the intra-regional accessibility by definition is zero. Moreover, several municipalities have no company R&D and/or university R&D.

3.2 Regression results

Table 3.2 presents the OLS parameter estimates of Equation (3.1) on the full sample, i.e. all 286 municipalities. The dependent variable is the change in value-added per employee during the period 1993-2001. The table include the results from three regressions. The first one is with weighted accessibilities to both company R&D (CRD) and university R&D (URD) as regressors. As can be seen from the table, the Variance Inflation Factor (VIF) indicates serious problems with multicollinearity.[8] Hence, there is a high risk that the parameter estimates are distorted. As a consequence we are therefore only going estimate and interpret the results from an equation where university R&D accessibilities and company R&D accessibilities are used as regressors separately (the second and the third regression in Table 3.2)

The results shows that the parameter estimates for the weighted intra-regional accessibility variables are statistically significant and positive for both university and company R&D. The parameter estimates for the weighted intra-municipal accessibility variables are also statistically significant and positive. Moreover, the parameter estimates for extra-regional accessibility are insignificant. This suggests that the effect of knowledge resources on the growth of a municipality is limited to those knowledge resources located within the functional region.

[8] Variance Inflation Factor, VIF = $1/(1-R^2)$, where R^2 is the goodness of fit measure for the auxillary regressions. For instance, "weighted intra-regional accessibility to university R&D" on LHS and the other explanatory variables on RHS (Greene, 1993, pp. 267).

Table 3.2: Marginal effects on the change in value-added per employee during the period 1993-2001 for Swedish municipalities (n = 286)

	1) Both URD and CRD		2) URD		3) CRD	
Variable	coeff	VIF	coeff	VIF	coeff	VIF
Intercept	156753 (11.26)		153041 (11.0)		150440 (10.7)	
$\omega_s A_{sM}^{URD}$	471.5 (2.34)	*6.30*	239.4 (2.11)	1.49		
$\omega_s A_{sR}^{URD}$	289.5 (0.59)	*13.05*	594.0 (3.42)	1.60		
$\omega_s A_{sE}^{URD}$	354.4 (0.61)	*4.33*	-71.95 (-0.18)	1.67		
$\omega_s A_{sM}^{FRD}$	-87.13 (-1.17)	*4.29*			74.83 (2.00)	1.27
$\omega_s A_{sR}^{FRD}$	138.6 (0.56)	*15.21*			258.5 (2.51)	1.25
$\omega_s A_{sE}^{FRD}$	-835.3 (-1.48)	*6.11*			128.4 (0.96)	1.26
E_s	-200.3 (-4.49)	1.34	-196.3 (-4.29)	1.32	-189.7 (-4.15)	1.31
$D_s^{mig(+)}$	-334.2 (-0.03)	1.81	-3376 (-0.34)	1.79	-3491 (-0.34)	1.76
D_{s1}^{pop}	29403 (1.29)	1.65	19602 (0.84)	1.56	33724 (1.74)	1.61
D_{s2}^{pop}	32974 (2.30)	1.39	35783 (2.51)	1.35	34624 (2.23)	1.36
R^2	0.274		0.256		0.247	

*) statistical significance at the 0.05 level in bold.
**) t-values in brackets.
***) standard errors are calculated using White's (1980) heteroscedasticity-consistent covariance matrix.

The estimated parameter for the entrepreneurship variable comes out as significant and negative in the estimations. This means that value-added per employee has shown a limited growth in municipalities with many 1-person firms per employee. A possible explanation for this result could be that firm formation by an individual is a response to few alternative occupations, (see e.g. Storey, 1994). This would mean that limited municipal growth translates into few occupation alternatives, which pushes start-ups by individuals[9]. Moreover, the dummy for positive net migration is statistically insignificant in the estimations. As indicated by the parameter estimate of D_{s2}^{pop} , municipalities with a population between 50 and 100 000 has on average experienced a higher growth in the investigated period compared to municipalities with smaller populations. The parameter estimate of D_{s1}^{pop} is also positive, but its statistical significance can not be proved in the estimations. The fit of each model, measured by the R^2, is approximately 0.25.

Table 3.3 reports the results of the regressions when the 286 municipalities are divided into the three groups according to the discussion in Section 2.3. The variables are the same as in Table 3.2 with one exception. The two population dummy variables are reduced to one, D_{s}^{pop} , which takes the value 1 if the population in a municipality exceeds 50 000 and zero otherwise. The setup with two separate population dummies was not appropriate since the group “Other municipalities in small LLMRs” does not include any municipality with a population larger than 100 000.

Let us now study how the model is able to explain the variation in the dependent variable in the six regressions in Table 3.3. According to the R^2-values the best fit is for the group “other municipalities in large LLMRs”. The fit is slightly higher with the university R&D accessibilities (0.589) compared to the fit in the regression with the company R&D accessibilities (0.567). For the group “largest municipality in all LLMRs” the situation is reversed, with the accessibilities to company R&D being the ones that explains the variations in the dependent variable the most. The R^2-values are, however, much smaller, 0.215 and 0.257 for university R&D and company R&D, respectively. The change in growth in “other municipalities in small LLMRs” (the third group), is only affected by the entrepreneurship variable. The effect is negative and statistically significant. The model is not able to pick up much of the variation in the dependent variable for this group and is of course manifested in small R^2-values.

[9] In this context, it should be stressed that in Sweden, people can apply for a government grant to start their own firm from a public employment office provided that they are (i) unemployed or at the risk of being unemployed, (ii) registered at a public employment office and (iii) at least 20 years old.

It is interesting to analyse the results for the three variables revealing the spatial structure, i.e. intra-municipal, intra-regional and inter-regional accessibility to university and company R&D. The change in value-added per employee in the largest municipalities in each local labour market region is above all significantly influenced by the intra-regional accessibility to R&D. Intra-municipal and inter-regional accessibility to university R&D show no significant influence. On the other hand, it seems like the intra-municipal and the inter-regional accessibility to company R&D significantly affects the dependent variable.

The change value-added per employee in other municipalities located in large local labour markets is in particular dependent upon intra-municipal accessibility to R&D even if intra-regional accessibility to R&D also has an influence (statistically significant at least for university R&D).

Our results indicate that growth in the largest municipality in all LLMRs is stimulated by high intra-municipal, intra-regional and inter-regional accessibility to company R&D and by high intra-regional accessibility to university R&D. Most of the leading establishments in these municipalities belong to multi-establishment companies, which often are multinational companies. Multinational companies are responsible for more than 90 percent of all company R&D in Sweden. One possible interpretation is that intra-company knowledge and innovation networks allow knowledge to flow efficiently between establishments within companies in the largest municipalities and thus stimulating growth in these municipalities. We find it harder to explain why intra-municipal accessibility to university R&D turns up insignificant, while intra-regional accessibility to university R&D shows up significant.

Table 3.3: Marginal effects on the change in value-added per employee during the period 1993-2001 for Swedish municipalities. The municipalities dived into three groups.

	Largest municipality in all LLMRs (n = 81)		Other municipalities in large LLMRs (n = 61)		Other municipalities in small LLMRs (n = 144)	
Variable	URD	CRD	URD	CRD	URD	CRD
Intercept	207053 (6.25)	213690 (6.40)	115742 (3.87)	105603 (3.22)	145203 (5.63)	145039 (5.82)
$\omega_s A_{sM}^{URD}$	94.81 (0.64)		723.3 (3.84)		-67580 (-1.42)	
$\omega_s A_{sR}^{URD}$	846.4 (2.34)		558.4 (2.97)		-6780 (-1.28)	
$\omega_s A_{sE}^{URD}$	134.6 (0.14)		178.9 (0.33)		1357 (1.33)	
$\omega_s A_{sM}^{FRD}$		17.12 (1.97)		906.2 (6.58)		7161 (1.42)
$\omega_s A_{sR}^{FRD}$		1125 (5.69)		205.0 (1.90)		-3147 (-1.81)
$\omega_s A_{sE}^{FRD}$		205.6 (2.67)		599.0 (0.76)		-946.6 (-0.88)
E_s	-351.0 (-2.83)	-377.6 (-3.02)	-117.1 (-1.93)	-98.85 (-1.44)	-183.1 (-2.10)	-177.0 (-2.12)
$D_s^{mig(+)}$	-11020 (-0.53)	-15595 (-0.75)	-10198 (-0.45)	-9019 (-0.38)	9066 (0.52)	22950 (1.30)
D_s^{pop}	23700 (1.20)	22900 (1.16)	36574 (1.34)	25381 (0.86)	11477 (0.45)	22458 (1.40)
R^2	0.215	0.257	0.589	0.567	0.082	0.089

*) statistical significance at the 0.05 level in bold.
**) t-values in brackets.
***) standard errors are calculated using White's (1980) heteroscedasticity-consistent covariance matrix.

For other municipalities in large LLMRs we find that intra-municipal accessibility to both university and company R&D is significant at the 5 percent level. Intra-regional accessibility to university and company R&D is also significant, even if the significance for the company R&D is at the 10 percent level. Thus, knowledge driven growth in these municipalities is dependent upon R&D efforts within the own municipality as well as within the rest of the LLMR. Knowledge generated outside the region play no direct role for the growth in these municipalities.

In other municipalities in small LLMRs growth clearly depend upon other factors than R&D accessibility. These municipalities makes up about 50 percent of all municipalities in Sweden, which indicates that growth stimulating policies must contain more instruments than stimulation of knowledge production and infrastructure investments.

4. Conclusions

Knowledge is maintained as a core variable for growth in a large set of contemporary theories. Both the endogenous growth theory and the innovation systems literature, for instance, suggest that growth depends on knowledge production activities. In these approaches, such activities require accessibility to the stock of accumulated knowledge. However, accessibility to knowledge resources differs between locations. If knowledge is not easily accessible at every point in space, the location of knowledge production and the characteristics of knowledge flows become critical issues in understanding economic growth.

In this paper we have analyzed the relationship between knowledge accessibility and regional growth. The knowledge resource used in our model R&D conducted at universities and in companies. A precise definition of accessibility was introduced and calculations were based on actual travel time distances. Using data at the municipality level in Sweden, the hypothesis that knowledge accessibility has a positive effect on growth cannot be rejected. The knowledge accessibility in a given period has a statistically significant effect on the growth in value-added per employee in subsequent periods.

The total accessibility of a municipality was divided into three types, (i) intra-municipal accessibility, (ii) intra-regional accessibility and (iii) extra-regional accessibility. The paper has shown that this division gives a clear indication of that there is spatial dependence in the sense that the knowledge resources in a given municipality tend to have a positive effect on the growth of another municipality, conditional on that the municipalities belongs to the same functional region. Thus, the results of the analysis indicate that knowledge flows transcend municipal borders, but that they tend to be bounded within functional regions.

The findings in the paper provide support for the theories that emphasize the role of knowledge for growth. However, the paper demonstrates that spatial proximity to knowledge resources is important to materialize the positive effect of such resources. Accessibility to knowledge in space is thus imperative. The paper has referred to the literature suggesting that knowledge production activities have a predominant tendency to cluster spatially. If this is so, the results imply that growth, everything else equal, will primarily take place in locations with high accessibility to such clusters. Hence, the results provide support for a relationship between location and growth, which in a general sense indicate path dependencies in growth processes.

As shown in the paper, however, knowledge accessibility is formed by the location pattern of knowledge resources combined with infrastructure. The interesting conclusion from this is that since both infrastructure investments and location decisions, and hence knowledge accessibility, can be influenced by policy, so can the phenomena dependent on knowledge accessibility. The results of the paper thus suggest that policies can potentially affect growth through location incentives and infrastructure investments. Which of these strategies are more or less efficient is a question that needs further research to be answered.

References

Acs, Z.J., L. Anselin & A. Varga (2002), "Patents and Innovation Counts as Measures of Regional Production of Knowledge", *Research Policy 31*, 1069-1085

Adams, J. & F. Pigliaru (1999) (eds.), *Economic Growth and Change*, Cheltenham; Edward Elgar

Almeida, P. & B. Kogut (1999), "The Localization of Knowledge and the Mobility of Engineers", *Management Science 45*, 905-917

Andersson, M. and C. Karlsson (2006), "Regional Innovation Systems in Small and Medium-Sized Regions. A Critical Review and Assessment" in Johansson, Karlsson and Stough (2006 (Eds.) (Forthcoming)

Andersson, M. and C. Karlsson (2004), "The Role of Accessibility for Regional Innovation Systems", in Karlsson, Flensburg and Hörte (2004) (Eds.), 283-310

Armstrong, H.W. & R.W. Vickerman (1995) (eds.), *Convergence and Divergence among European Regions*, London; Pion

Arrow, K. (1962), "Economic Welfare and the Allocation of Resources for Invention", in Nelson (1962) (ed), 609-626

Bal, F. & P. Nijkamp (1998), "Exogenous and Endogenous Spatial Growth Models", *The Annals of Regional Science 32*, 63-89

Barro, R.J. & X. Sala-i-Martin (1995), *Economic Growth*, Cambridge, MA; The MIT Press

Braunerhjelm, P. & B. Borgman. (2004), Geographical concentration, entrepreneurship and regional growth: evidence from regional data in Sweden, 1975-99, *Regional Studies 38*, 929-947

Caniëls, M.C.J. (2000), *Knowledge Spillovers and Economic Growth. Regional Growth Differentials across Europe*, Cheltenham; Edward Elgar

Carlino, G.A.(2001), "Knowledge Spillovers: Cities' Role in the New Economy", *Federal Reserve Bank of Philadelphia Business Review*, Q4,17-23

Cheshire, P. & G. Carbonaro (1995), "Convergence-Divergence in Regional Growth Rates: An Empty Black Box?", in Armstrong & Vickerman (1995) (eds.), 89-111

Cohen, W., & D. Levinthal, (1990), Absorptive capacity: A new perspective on learning and innovation, *Administrative Science Quarterly, 35*, 128-152

Feldman, M. (1994), *The Geography of Innovation*, Boston; Kluwer Academic Publishers

Feser, E.J. (2003), "What Regions Do Rather than Make: A Proposed Set of Knowledge-based Occupation Clusters", *Urban Studies 40*, 1973-1958

Fischer, M.M. & J. Fröhlich (2001) (Eds.), *Knowledge, Complexity and Innovation Systems*, Berlin; Springer-Verlag

Fischer, M.M., L. Suarez-Villa & M. Steiner (1999) (eds.), *Innovation, Networks and Localities*, Berlin; Springer-Verlag

Florida, R. (2000), *Competing in the Age of Talent: Quality of Place and the New Economy*, Pittsburgh, PA; R.K. Mellon Foundation, Heinz Endowments, Sustainable Pittsburgh

Florida, R. (2002), *The Rise of the Creative Class*, New York; Basic Books

Fujita, M. & J.-F., Thisse (2003), “Does Geographical Agglomeration Foster Economic Growth? And who Gains from It?”, *The Japanese Economic Review 54*, 121-145

Glaeser, E., et al. (1992), “Growth in Cities”, *Journal of Political Economy 100*, 1127-1152

Greene, W.H. (1993) *Econometric Analysis*, 2nd Ed, Mcmillan Publishing Company

Jaffe, A., M. Trajtenberg & R. Henderson (1993), “Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations”, *Quarterly Journal of Economics 108*, 577-598

Johansson, B. (2005), Parsing the Menagerie of Agglomeration and Network Externalities, in Karlsson, Johansson & Stough (2005) (Eds.), 107-147

Johansson, B., C. Karlsson and R. Stough (2006) (Eds.), *The Emerging Digital Economy: Entrepreneurship, Clusters and Policy*, Berlin; Springer (Forthcoming)

Johansson, B., J. Klaesson & M. Olsson (2002), “Time Distances and Labor Market Integration”, *Papers in Regional Science 81*, 305-327

Johansson, B., J. Klaesson & M. Olsson (2003), ”Commuters’ Non-Linear Response to Time Distances”, *Journal of Geographical Systems*, 5, 315-329

Karlsson, C. (1997), “Product Development, Innovation Networks and Agglomeration Economies”, *The Annals of Regional Science 31*,

Karlsson, C., P. Flensburg and S.-Å. Hörte (2004) (Eds.), *Knowledge Spillovers and Knowledge Management*, Cheltenham; Edward Elgar

Karlsson, C., B. Johansson & R.R. Stough (2005) (Eds.), *Industrial Clusters and Inter-Firm Networks*, Cheltenham; Edward Elgar

Karlsson, C. and A. Manduchi (2001), “Knowledge Spillovers in a Spatial Context – A Critical Review and Assessment”, in Fischer and Fröhlich (2001) (Eds.), 101-123

Klaesson, J. (2001), “Spatial Interaction Models and Concepts: a Review of the Gravity Theory”, Jönköping International Business School, Jönköping **(**mimeo)

Mathur, V.K. (1999), “Human Capital-Based Strategy for Regional Economic Development”, *Economic Development Quarterly 13*, 203-216

Maurseth, P. & B. Verspagen (1998), “Knowledge Spillovers in Europe and its Consequences for Systems of Innovation”, Paper prepared for the TSER project ‘Technology, Economic Integration and Social Cohesion’ workshop in Gothenburg

Nelson ,R.R (1962), *The Rate and Direction of Inventive Activity*, University-National Bureau Conference Series, 14, New York: Arno Press

Nijkamp, P. & J. Poot (1998), “Spatial Perspectives on New Theories of Economic Growth”, *The Annals of Regional Science 32*, 7-37

Polanyi, M. (1996), *The Tacit Dimension*, London; Routledge & Kegan Paul

Storey, D. (1994), *Understanding the Small Business Sector*, London; Routledge

Swan, T.(1956), “Economic Growth and Capital Accumulation”, *Economic Record 32*, 334-361

Thompson, W.R. & P.R. Thompson (1985), “From Industries to occupations: Rethinking Local Economic Development”, *Economic Development Commentary 9*, 12-18

Thompson, W.R. & P.R. Thompson (1987), “National Industries and Local Occupational Strengths: The Cross-hairs of Targeting”, *Urban Studies 24*, 547-560

Varga, A. (1999), “Time-Space Patterns of US Innovation: Stability or Change? A Detailed Analysis Based on Patent Data”, in Fischer, Suarez-Villa & Steiner (1999) (eds), 215-234

Verspagen, B. & W. Schoenmakers (2000), "The Spatial Dimension of Knowledge Spillovers in Europe: Evidence from Firm Patenting Data", Maastricht; Merit

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

Weibull, J. (1980), "On the Numerical Measurement of Accessibility", *Environment and Planning A 12*, 53-67

Appendix

Descriptive statistics of the variables in the analysis (n = 286 municipalities).

Variable	Explanation	Mean	Median	Std.dev
Δy_s	Change in value-added per employee 1993-2001	103 876.20	94 487.47	75 638.87
$\omega_s A_{sM}^{CRD}$	Weighted intra-municipal accessibility to company R&D	14.53	0.07	117.48
$\omega_s A_{sM}^{URD}$	Weighted intra-municipal accessibility to university R&D	8.86	0.00	63.54
$\omega_s A_{sR}^{CRD}$	Weighted intra-regional accessibility to company R&D	24.33	0.29	91.16
$\omega_s A_{sR}^{URD}$	Weighted intra-regional accessibility to university R&D	11.04	0.02	39.28
$\omega_s A_{sE}^{CRD}$	Weighted extra-regional accessibility to business R&D	8.18	3.48	20.42
$\omega_s A_{sE}^{URD}$	Weighted extra-regional accessibility to university R&D	5.90	0.61	15.59
$\omega_s T_{sE}^{P}$	Weighted extra-regional accessibility to patent stock	5.05	2.15	12.01
E_s	Entrepreneurship (number of 1-person firms per employed)	0.03	0.02	0.01
$D_s^{mig(+)}$	Dummy, 1 if municipality s had positive net migration 1993-2001, 0 otherwise.	0.34	0.00	0.34
D_{s1}^{pop}	Dummy, 1 if municipality s have a population > 100 000.	0.04	0.00	0.19
D_{s2}^{pop}	Dummy, 1 if municipality s have a population between 50 000 and 100 000.	0.13	0.00	0.33