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## **Regional Productivity and Accessibility to Knowledge and Dense Markets<sup>1</sup>**

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# Regional Productivity and Accessibility to Knowledge and Dense Markets

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## Abstract

Accessibility to knowledge and local service markets can be assumed to explain regional growth performance. The role of regional supply of services and educated labour with respect to regional development are stressed by many researchers. In this paper we make an empirical analysis using panel data for Swedish municipalities. The purpose is to analyse the relationship between regional productivity measures as gross regional product per square kilometre and accessibility to educated labour. We also acknowledge the extension of the regional economy in terms of functionality and access to population as a measure of accessibility to labour and to purchasing power. We estimate first a cross-section model by using OLS. Second we employ a panel data model, using time distance access to population and the share local labour force with longer higher education as explanatory variables. In the analysis we compare the results for Sweden from the different models with other studies in this field. We find that local externalities for increasing returns are very important in the Swedish economy. Our estimated models yields a high level of goodness of fit, and the results indicates that the elasticity for longer higher education and population density are around unity in the Swedish economy with respect to performance of regional gross domestic product per square kilometre.

**Keywords:** Density, Agglomeration, Productivity, Sweden, Spatial, Regional, accessibility

**JEL Classification:** D240; J240; O470; R110; R230; R400

## **1. Introduction**

The significance of localised agglomeration externalities and increasing returns, and how they relate to spatial differences in labour productivity is analysed by Baptista (2003). He develops an empirical model of local productivity following the work of Ciccone & Hall (1996), where the spatial density of economic activity is the source of aggregate increasing returns. Density is defined as the amount of labour, and human and physical capital per square kilometre. Density is assumed to affect productivity in several ways: (i) if there are externalities, such as knowledge spillovers, associated with the physical proximity of production activities and human capital, then density will spur innovation and productivity; (ii) areas with a high density of economic activities offer opportunities for a higher degree of specialisation, thus establishing a source of increasing returns; (iii) even if technologies have constant returns themselves, but the transportation of products from one stage of production to the next involves costs that rise with distance, then the technology for the production of all goods within a particular geographical area will still experience increasing returns (cf. Ohlin, 1933).

Ciccone and Hall (1996) found that capital accounts for some of the differences in productivity across U.S. states, but leaves most of the variation unexplained. Estimation of their model of locally increasing returns revealed that accounting for density of economic activity at the county level is crucial for explaining the variation of productivity at the state level. According to their estimates, a doubling of employment density in a county results in an increase of average labour productivity by 6 per cent. This degree of locally increasing returns explains more than half of the variation of output per worker across states.

Ciccone (2002) estimates agglomeration effects for France, Germany, Italy, Spain and the U.K. His estimations take into account endogeneity of the spatial distribution of employment and spatial fixed effects. His empirical results suggest that agglomeration effects in these European countries are only slightly smaller than the agglomeration effects in the U.S.: the estimated elasticity of (average) labour productivity with respect to employment density is 4.5 per cent compared to 5 per cent in the U.S.

When estimating his empirical model of local increasing returns using data for the UK, Baptista (2003) finds that accounting for the density of economic activity at the county level is essential for explaining geographical differences in productivity. He finds that the degree of locally

increasing returns has a highly significant effect on local output per worker. Moreover, the density of human capital has also a significant effect on productivity.

Even if interesting we find the work by Baptista (2003) as well as Ciccone and Hall (1996) and Ciccone (2002) deficient in a number of aspects. Doing analyses with data from the county level implies that the analysis is done based upon administrative regions and not functional economic regions. Measuring labour density as the number of employees per square kilometre disregards the well-known fact that regions with the same number of employees per square kilometre may differ substantially when it comes to accessibility to labour due to differences in infrastructure capital supply and in the working of the system for passenger transport.

The purpose of the current paper is to analyse the role of density for productivity growth in Swedish functional regions within a theoretical framework along the lines suggested by Rivera-Batiz (1988), Romer (1986) and Lucas (1988). Our study differs from the earlier studies of Baptista (2003) and others in several important respects. We work at a finer level of spatial disaggregation, which implies more observations. We introduce accessibility measures as a more proper measure of the potential of each region in terms of labour, and human, and physical capital. Given that we have observations for many years it is possible for us not only to use OLS-estimates but also to do panel data estimations. This means that we also are able to compare the results of different methodological approaches.

The outline of the paper is as follows: In Section 2 we present our theoretical background. The empirical model is developed in Section 3. Our data is described in Section 4, while our estimations and our discussion of our results can be found in Section 5. Section 6 concludes and gives suggestions for future research.

## **2 Economic density in functional regions and productivity growth**

### *2.1 Economic density in functional regions*

The most striking observation regarding the geography of economic activities is concentration (Krugman, 1991). The geographic concentration of firms and production is basically a reflection of the fact that economies of scale implying increasing returns to scale in production, whether direct or via spillovers in technology or human capital, has a very strong influence on location

patterns and the development of regions even when transport costs are small (Henderson, 1988; Fujita, Krugman & Venables, 1999). Without increasing returns firms and production could as well be evenly spread out over geographical space.

In the theoretical framework outlined here, the “functional region” is a prime concept. It is distinguished by its concentration of activities and of its infrastructure, which facilitates particularly high factor mobility within its borders (Johansson & Karlsson, 2001). In particular, the functional region is an integrated local labour market, sometimes referred to as a commuting region.

A functional region is in a fundamental way characterised by its density of economic activities, social opportunities and interaction options. From the perspective of the individual firm, density is a positive factor to the extent that it creates accessibility to households, firms and other economic actors. This density may relate to a specific industry. Such intra-industry density is an important phenomenon, in particular, for small and medium-sized functional regions. Density may also relate to all industries. Such industry-wide density exists mainly in metropolitan or other large functional regions with a large home market for local products.

The above discussion implies that economic density can be interpreted as inter-regional accessibility, where ‘region’ is defined as a functional region. However, in the discussion here it is not density *per se* but accessibility to economic resources and economic agents that matters. Accessibility is obtained by an appropriate combination of density and infrastructure and it is the interaction between these three factors that forms the core of regional economic development. If density increases and the infrastructure remain unchanged, congestion and other tensions may follow. As a consequence, accessibility is reduced and the value of density declines. Infrastructure without matching density, on the other hand, represents only idle opportunities.

The interpretation of economic density as intra-regional accessibility within a functional region to resources and to economic actors has several implications (Karlsson & Stough, 2002). Central place system and filtering-down models, for example, recognise in a general sense the importance of density of, i.e. accessibility to, purchasing power. A region with a high accessibility to purchasing power has a comparative advantage in the production of goods and services with contact intensive sales, i.e. with high geographical transaction costs. Location advantage and spatial product cycle models, on the other hand, focus on the density of, i.e. accessibility to, firms

producing similar or related products and specialised input suppliers and labour categories with regard to existing clusters. Metropolitan and large functional regions combine dense purchasing power with density on the supply side. Small and medium-sized regions can only achieve density on the supply side and are thus forced to specialize in the production of products with low geographical transaction costs.

Having outlined the general character of economic density a couple of question arises: What factors generate economic density? What role does economic density play for productivity and productivity growth? In the sequel, we will try to answer these questions.

## *2.2 The generation of economic density*

Economic density is the result of agglomeration of purchasing power and/or the agglomeration of production capacity. Agglomeration is in the urban economics literature assumed to generate agglomeration externalities defined as any economies or cost reductions, which are possible if a group of firms or households locate near each other. Much of the discussion of agglomeration economies has been based upon static concepts of agglomeration externalities (cf., Hendersson, 1986). However, to understand the generation of economic density we need dynamic formulations.

One dynamic model of agglomeration based upon learning economies was proposed by Lucas (1988). In this model workers learn from each other. When one worker becomes more productive, through education, training or learning-by-doing, all workers in a given location also become somewhat more productive. Using this idea of localised human capital spillovers fostering endogenous growth and combining this idea with agglomeration economies Black and Henderson (1999) presented a dynamic model of city formation.

An alternative dynamic model of agglomeration takes its starting point in the existence of internal economies of scale at the firm level, i.e. of increasing returns internal to firms, which implies that perfect competition no longer prevails. Assuming a monopolistically competitive market structure it is, for example, possible to demonstrate that the existence of non-transportable intermediate inputs produced with increasing returns imply agglomeration (Abdel-Rahman, 1988; Fujita, 1988; Rivera-Batiz, 1988). In a similar manner Krugman (1991) demonstrated that agglomeration

would result even when transport costs are small if there are internal economies to scale, as long as most workers are mobile.

However, the full exploitation of increasing returns presupposes a market potential that is large enough, i.e. large market potentials become economically meaningful phenomena only when there are firms with internal economies of scale (Karlsson & Stough, 2002). A large regional market potential is attractive for firms with internal economies of scale. Hence, such firms try to locate in regions, which offer large market potentials. This observation represents a basic dynamic mechanism, which generates regional growth and agglomeration in a self-reinforcing way. Having pronounced internal economies of scale, firms will locate in regions, which have large market potentials and, thus, some large regional markets evolve because firms with internal economies of scale locate there.

In this manner, a cumulative relationship is established, which is driven by the interaction between internal economies of scale, demand growth and geographical interaction costs. As a result, internal economies of scale at the firm level become a kind of external effect, which is mediated by the market. In larger urban regions these internal economies of scale become a kind of collective agglomeration advantage, meaning that the urban milieu as a whole is characterised by scale economies. It is only in a world with internal economies of scale at the firm level that geographical interaction costs in interplay with market forces can give rise to cumulative processes and agglomeration advantages (Krugman, 1993).

As long as cumulative effects generate an increasing market potential in a region, a market place for an increasing number of industries and firms with internal economies of scale is created, which generates increased economic density. But an increased economic density presupposes that suitable infrastructure is created in a process more or less parallel to the agglomeration process. This can be more tricky than it sounds since economic processes as a rule develop at a time scale that is much more rapid than the investments in new infrastructure (Johansson & Wigren, 1996).

However, there are limits to density. There are physical limits to density, and when density increases so will land, labour and commuting costs.

### *2.3 Economic density and productivity*

Cervero (2001) claims, that those large cities that are compact, and enjoy a good accessibility<sup>2</sup> matched by efficient transport infrastructure, i.e., large, dense cities, are among the most productive of all urban settlements. In what ways does economic density stimulate productivity? We may identify a number possible ways (cf, Henderson, 1986). We claim that each of the nine economies identified in this section are dynamic economies in the sense that firms that are dependent upon one or several of these economies will have advantages of locating in regions offering such economies. And when more firms locate in already dense regions, the density will increase, which will induce more firms to locate in these regions.

The identified economies can also be interpreted as dynamic in the sense that the larger these economies the larger the capacity of the actual regions to generate innovations. As regions become denser these economies tend to become more pronounced. Expressed in simple terms productivity improvements can be achieved in two major ways: (i) a more efficient production of existing products, and (ii) the introduction of new products. In the medium and long term we expect the second way to be most important for boosting productivity. It might be important to stress that the importance of the different economies for productivity might differ substantially between different sectors (cf. Feser, 2002) due to the character of the product produced, the production process used and industrial organisation of the sector (cf. Chinitz, 1961). For some industries there might even be diseconomies associated with urban density (Feser, 2002). As a general rule we shall expect young, knowledge-intensive and unstandardised products to be more dependent upon urban density than old and standardised products.

#### *2.31 Scale and specialisation economies and productivity*

1. Internal economies of scale – the larger the intra-regional accessibility to purchasing power, i.e. the higher the economic density, the higher the possibilities to take advantage of internal economies of scale at the firm level. The role of internal economies of scale as a cause of agglomeration economies was first taken up by Ohlin (1933) and later on by

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<sup>2</sup> We define this concept differently. See Section 4.



Hoover (1937 & 1948). Without the existence of scale economies in production, economic activities would be dispersed to save on transport costs.

2. Economies of intra-industry specialisation – the larger the intra-regional accessibility to purchasing power, i.e. the higher the economic density, the higher the degree of intra-industry specialisation. This kind of economies goes back to Smith (1776) and was taken up by Stigler (1951) and is closely related to the concept of localisation economies used by Ohlin (1933) and Hoover (1937 & 1948). Henderson (2003) looked at the evolution of productivity in manufacturing plants from high-tech and machinery industries in the U.S. and found that same-sector specialisation tends to have a positive effect on productivity.
  
3. Economies of infrastructure specialisation – the larger the intra-regional production volume, i.e. the higher the economic density, the higher the degree of specialisation in infrastructure provision. The influence of infrastructure has been studied in a number of studies in the 1980s and 1990s (cf. Batten & Karlsson, 1996). Empirical studies of the effects of infrastructure investments on economic outputs have generally recorded moderate rates of return (Boarnet, 1997). Using data from French and Korean cities, Prud'homme & Lee (1999) found the commuting speed elasticity of labour productivity to be around +0.30.
  
4. Labour market economies – the larger the intra-regional accessibility of labour, i.e., the denser the labour market, the lower are the search costs for workers with a specific education and training. This also is one of the three classical external economies identified by Marshall (1920). Dense regions reduce the search costs of workers with differentiated skills and employers with differentiated demands for labour, and thus improve matching in the labour market (Helsley & Strange, 1990; Simpson, 1992; Acemoglu, 1996). Greater availability of skilled, experienced workers grants firms substantial flexibility to expand and contract with minimal disruption (Krugman, 1991).

5. Labour and housing market economies – the larger the number of houses and workplaces, i.e. the denser the labour and housing markets, the lower the commuting times. This improves productivity since workers can spend more time at the workplace and less time to get to the workplace (Kain, 1993; Cervero, 1996)

### *2.32 Diversity economies and productivity*

6. Economies of inter-industry diversity – the larger the intra-regional accessibility to purchasing power, i.e. the higher the economic density, the higher the degree of inter-industry diversity. This kind of economies is closely related to the concept of urbanisation economies used by Ohlin (1933) and Hoover (1937 & 1948).
7. Economies of input specialisation – the larger the intra-regional production volume, i.e. the higher the economic density, the higher the degree of specialisation in input provision, and thus the larger the degree of diversification in input provision. This is one of the three classical external economies identified by Marshall (1920). Ohlin (1933) also identified economies of input specialisation but used the concept inter-industry linkages for these phenomena. The ready availability of specialised firms in accounting, law, advertising and different technical fields can reduce the costs of other firms in metropolitan areas (Krugman, 1993). The economies of input specialisation do come from three sources (Feser, 2002): (i) the need for a firm to produce its inputs in-house (and at a higher cost) is reduced if the local market potential is sufficient to support contract suppliers that serve multiple producers (Scott, 1986), (ii) physical proximity to input suppliers permits greater flexibility in that inputs can be more easily obtained in smaller quantities or on an as-needed basis (Goe, 1991), and (iii) buyers can more easily work directly with their suppliers when the latter are located nearby (Burt, 1989; Newman, 1989; Helper, 1991; Imrie & Morris, 1992; Klier, 1994)

8. Demand economies of new products – the larger the intra-regional accessibility to purchasing power, i.e. the higher the economic density, the larger the diversity of demand, and the easier it is for firms to find customers for new products. This kind of economies forms a cornerstone in spatial product cycle theories and filtering-down theories (Karlsson, 1999).

The importance of diversity for productivity is obvious considering the argument of Jacobs (1969) that diversified urban regions play a strategic role in fostering innovations. Quigley (1998) analyses the agglomerative implications of diversity in cities. A number of established empirical findings support Jacobs' argument. Henderson, Kuncoro & Turner (1995) show, that urban diversity is indeed important for attracting new and innovative activities. Harrison, Kelley & Gant (1996) and Kelley & Helper (1999) study the adoption of new production processes by individual establishments in the U.S. belonging to the three-digit machine-making industries. They show that a diversity of local employment contributes significantly towards the adoption of new production processes. Feldman & Audretsch (1999) find that local diversity has a strong positive effect on the development of new products reported in trade journals in the U.S. Duranton & Puga (2001) develop the micro-foundations for the role that diversified cities play in fostering innovation.

### *2.33 Communication economies and productivity*

9. Economies of communication between firms – the larger the intra-regional accessibility of firms, i.e. the denser the location of firms, the more rapid do information, knowledge and innovations spread, i.e. the larger are the knowledge spillovers. This is the third of the three classical external economies identified by Marshall (1920). Today, there exists a rich literature on knowledge spillovers (Karlsson & Manduchi, 2001). Knowledge spillovers are actually of two varieties (Robinson, 1931): mobile and immobile. The concept of mobile knowledge spillovers captures the generalised technological progress, embodied as well as disembodied, that occurs over time and in principle at a global scale. However, that technological progress occurs at a global scale does not imply equal availability of technological knowledge in all countries and regions of the world (Romer, 1994). Large,

dense regions with good national and international air connections, leading research universities and major multi-national corporations will certainly have a superior availability of technological knowledge compared to other regions, which will stimulate productivity in these regions. The findings in Jaffe, Trajtenberg and Henderson (1993) and Adams & Jaffe (1996) also seem to be evidence that immobile or localised knowledge spillovers are a critical source of local scale externalities. Localised knowledge spillovers are likely to be strongest in regions with high rates of innovation and knowledge creation (Feser, 2002). Firms localised in the midst of such innovative regions are likely to become more productive as they learn more quickly from neighbouring firms and appropriate external effects from private and public research and development activities (Cooke & Morgan, 1998; Cooke, Boekholt & Tödtling, 2000). One major question concerns whether learning mainly takes place within or between industries. Glaeser *et al.* (1992), for example, interpret Romer (1986) as predicting that knowledge spillovers will be most significant among firms in the same industry. The exact mechanisms generating localised knowledge spillovers are not totally clear. One idea is that knowledge spillovers are mainly embedded in people (Zucker, Darby & Armstrong, 1998; Zucker, Darby & Brewer, 1998; Almeida & Kogut, 1999). In knowledge spillovers are embedded in people productivity and wages should reflect the accumulation of knowledge (Møen, 2000). That local average human capital levels affect individual earnings has been shown by Rauch (1993).

### **3. Empirical model**

In this section we present a model explaining total factor productivity at the regional level, which accommodates the effects of economic density and that can be used for empirical estimations. The model is a variant of the model used by Baptista (2003). We also extend the model along the lines suggested by Ciccone (2002).

The model contains three factors of production: land, labour and capital. The basic production function describes the output produced per square kilometre ( $q_r/a_r$ ) in a functional region  $r$  as a function of the input of labour per square kilometre ( $l_r/a_r$ ) and the volume of capital per square

kilometre  $(k_r/a_r)$ .<sup>3</sup> The agglomeration externality associated with economic density is assumed to depend multiplicatively output per square kilometre  $(q_r/a_r)$  with a constant elasticity of density  $(\lambda - 1)/\lambda$ . The basic production function for labour and capital is assumed to have a Cobb-Douglas-form with constant returns to scale and with the labour elasticity  $\beta$ . The labour accessibility in each functional region is weighted with a variable  $e_r$ , measuring labour efficiency. The total output in region  $r$  is then determined by<sup>4</sup>

$$q_r = a_r A_r \left[ \left( \frac{e_r l_r}{a_r} \right)^\beta \left( \frac{k_r}{a_r} \right)^{(1-\beta)} \right]^\alpha \left( \frac{q_r}{a_r} \right)^{(\lambda-1)/\lambda} \quad (3.1)$$

where  $\alpha$  is the production elasticity of the combined labour and capital input and  $A_r$  is a region-specific Hicks-neutral technology factor. (3.1) yields the following output per square kilometre in a functional region:

$$\frac{q_r}{a_r} = A_r^\lambda \left[ \left( \frac{e_r l_r}{a_r} \right)^\beta \left( \frac{k_r}{a_r} \right)^{(1-\beta)} \right]^\gamma \quad (3.2)$$

where  $\gamma = \alpha\lambda$ .

As capital stock data normally is lacking at the regional level a demand function for capital is derived assuming that the price of capital  $i$  is everywhere the same. Assuming that  $i$  equals the marginal product of capital we get:

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<sup>3</sup> All space in a functional region is assumed to be equally productive.

<sup>4</sup> Labour accessibility is assumed to be the same everywhere in each functional region and capital is assumed to be evenly dispersed over space in each functional region.

$$\frac{k_r}{a_r} = \frac{\alpha(1-\beta)}{i} \left( \frac{q_r}{a_r} \right) \quad (3.3)$$

(3.3) inserted in (3.2) yields

$$\frac{q_r}{a_r} = A_r^\omega \phi \left( \frac{e_r l_r}{a_r} \right)^\theta \quad (3.4)$$

where  $\phi$  is a constant that depends upon the interest rate and where

$$\omega = \frac{\lambda}{1-(1-\beta)\gamma} \quad (3.5)$$

and

$$\theta = \frac{\beta\gamma}{1-(1-\beta)\gamma} \quad (3.6)$$

To operationalise the labour efficiency variable we use the following relationship:

$$e_r = h_r^\eta \quad (3.7)$$

where  $h_r$  is the share of employees in region  $r$  that holds a university degree and  $\eta$

is the elasticity of education. If we insert (3.7) in (3.4) we get

$$\frac{q_r}{a_r} = \phi A_r^\omega \left( \frac{h_r^\eta l_r}{a_r} \right) \theta \quad (3.8)$$

If we take the natural logarithms for (3.8) we get the following equation that will be used for estimations:

$$\ln \left( \frac{q_r}{a_r} \right) = \ln \phi + \psi \ln h_r + \theta \ln \left( \frac{l_r}{a_r} \right) + u_r, \text{ where } \psi = \eta \theta \quad (3.9)$$

We claim that accessibility<sup>5</sup> to labour is a measure superior to labour input per square kilometre since it also acknowledges the standard of the system for personal travel. To acknowledge the possibility of spillovers within and between regions we formulate the following equation to be used in our estimations:

$$\ln \left( \frac{q_r}{a_r} \right) = \ln \phi + \psi \ln h_r + \theta \ln(a_r^I) + \sigma \ln(a_r^{II}) + \mu(a_r^{III}) + u_r \quad (3.10)$$

where  $a_r^I$  is intra-municipal accessibility to labour,  $a_r^{II}$  is intra-regional accessibility to labour, and  $a_r^{III}$  stands for interregional accessibility to labour in region  $r$ .

#### 4. The accessibility measure

In this paper we claim that accessibility to labour is a superior measure of density than the number of employees per square kilometre, since it also takes into account the quality of the systems for personal travel and commuting. The accessibility measures that will be used are

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<sup>5</sup> The concept of accessibility is introduced in Section 4.

based on Weibull (1976) and are constructed from two major principles: (i) the size of the attraction in the destination influences the propensity to travel to the destination positively, and (ii) the time distance to the destination from the location of potential travellers influences the propensity to travel to the destination negatively. Weibull (1976) shows, that a specific type of accessibility measure is theoretically consistent, and fulfils all necessary qualifications. Weibull (1980) claims 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.

In this paper we distinguish between three types of accessibility: intra-municipal, intra-regional and inter-regional. Regarding intra-municipal accessibility, consider a set of zones or nodes ( $j = 1, \dots, m$ ) within a municipality  $r$ . The density of contact options of each zone, i.e., its contact value, is denoted by  $A_j$ . For a given infrastructure,  $\bar{I}_r$ , the intra-regional accessibility increases as the  $A_j$ -values are augmented, given that the infrastructure capacity is sufficient. As interaction increases and the capacity limits of the infrastructure are reached, congestion effects will emerge and, hence, the accessibility is reduced.

For a given zone the accessibility to the other zones within the urban region can be described as follows:

$$a_{rj} = \sum_{k=1}^m \exp\{-\lambda_r d_{jk}\} A_k \quad (4.1)$$

where  $d_{jk}$  represents some relevant distance measure and where  $\lambda_r$  signifies the distance sensitivity of economic actors. From (4.1) it is possible to calculate an average accessibility value  $a_r^I = [a_{r1} + a_{r2} + \dots + a_{rm}] / m$ . The latter value can also be interpreted as a measure of the intra-municipal accessibility, i.e., the overall density of the municipality. If the density is increased while the infrastructure remains unchanged, the product  $\lambda_r d_{jk}$  will increase for each link( $j, k$ ), and this will reduce accessibility. Hence, in this way density and infrastructure capacity simultaneously determine accessibility.



The intra-regional accessibility of a municipality  $r$ ,  $a_r^{II}$ , can be defined as

$$a_r^{II} = \sum_{j=1}^n \exp\{-\lambda_{II} d_{jr}\} A_j \quad (4.2)$$

where  $j$  represents all municipalities in the region except  $r$ ,  $\lambda_{II}$  represents the time sensitivity for intra-regional travel,  $d_{jr}$  represents the time distance between municipalities  $j$  and  $r$  and  $A_j$  represents the population in municipality  $j$ .

The inter-regional accessibility of a municipality  $r$  in a given region to all other regions  $a_r^{III}$  can be described by a formula which resembles (4.1) and (4.2):

$$a_r^{III} = \sum_{l=1}^s \exp\{-\lambda_{III} d_{lr}\} A_l \quad (4.3)$$

where  $l$  represents all municipalities except the municipalities the region where municipality  $r$  is located,  $\lambda_{III}$  represents the time sensitivity for inter-regional travel,  $d_{lr}$  represents the time distance between municipality  $l$  and municipality  $r$ , and  $A_l$  represents the population of municipality  $l$ .

The time distances used are car travel time distances according to the National Road Authority in Sweden. The relevant time distance ranges are illustrated in Table 4.1. The time sensitivity parameters are taken from Johansson, Klaesson & Olsson (2002). These differ in size in the following way:  $\lambda_{II} > \lambda_{III} > \lambda_I$ , which means that time friction is greatest for time intervals of the size 15-50 minutes, smaller for intervals longer than 50 minutes and smallest for very short time distances.

**Table 4.1** Categories of accessibility, travel time distances and contact types

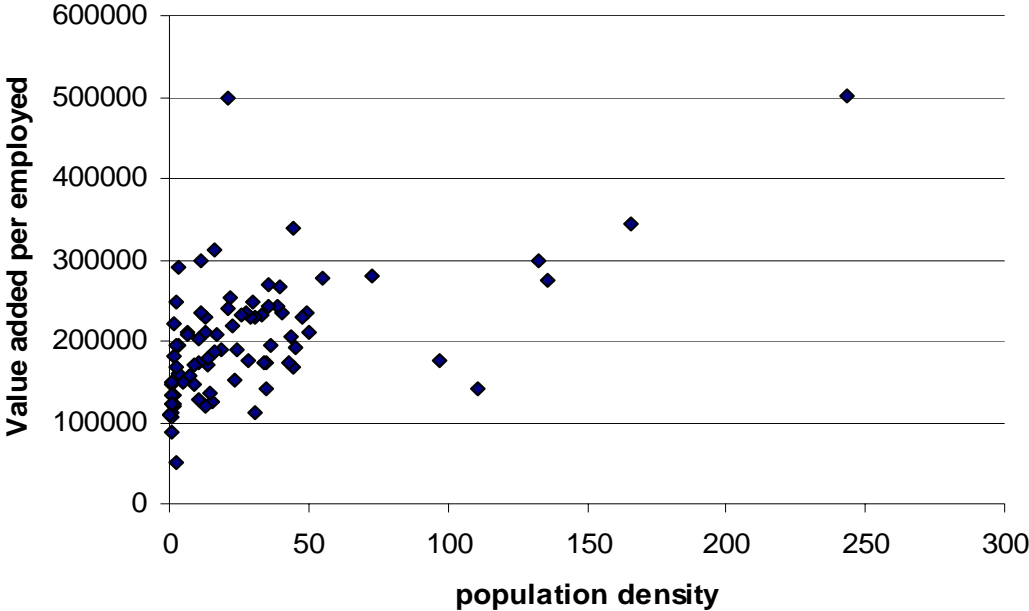
<b>Accessibility</b>	<b>Approximate time distance</b>	<b>Type of contacts</b>
Local	5-15 minutes	Several unplanned contacts per day
Intra-re-gional	15-50 minutes	Contacts and travels made on regular basis (commuting), once per day
Interregional	>50 minutes	planned contacts, low frequency

Source: Johansson, Klaesson & Olsson (2002)

## **5. Data and descriptive statistics**

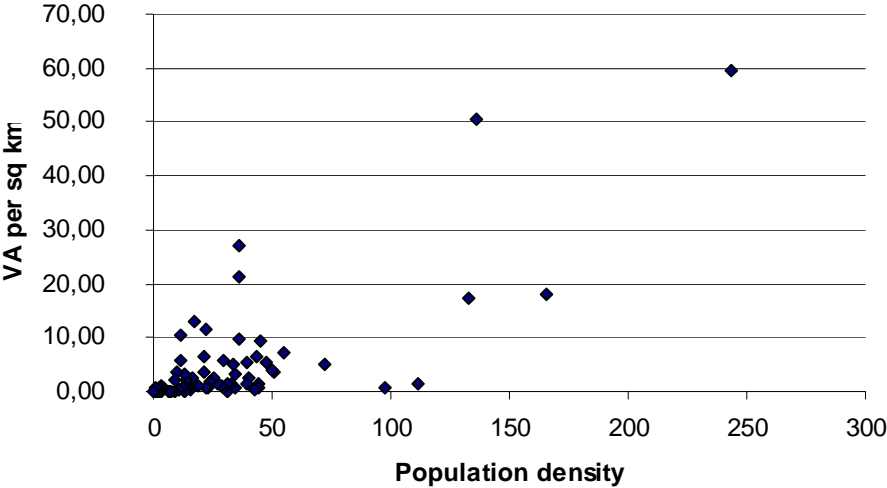
In the empirical analysis we use data for output (gross domestic production) on municipal level for the years 1997-00. The Swedish economy is divided into 288 municipalities. The analysis is based on firm level data for gross value added from Statistics Sweden. We also make use of a definition of functional regions that divides the Swedish economy into 81 local labour market regions, which could be considered to be functional regions. As presented earlier we focus our study on how regional production per square kilometre is explained by accessibility to population as a proxy for accessibility to labour and to purchasing power and the share of the labour force with a longer higher education. Exploring the original data set we find that value added per employed and population density in local labour markets in Sweden have a positive relationship. As we can see from Figure 1, there are a few high performing regions that have a high value added per capita, which are crucial for the significance of the relationship.

**Figure 5.1** Value Added per Employee and Population Density in Local Labour Market Regions in Sweden 2000



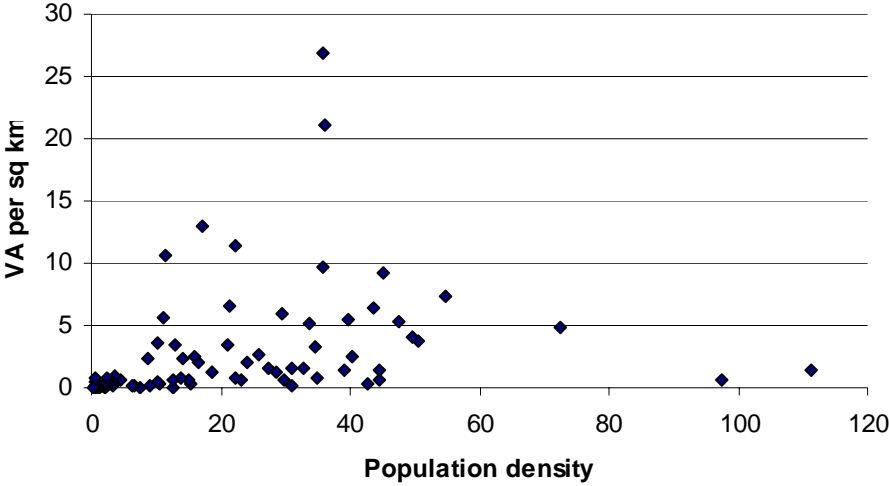
When we turn to the relationship between value added per square kilometre and population density we find a similar positive relationship and again there are a few observations that are important for the significance of the relationship (Figure 5.2).

Figure 5.2 Value Added per Square Kilometre and Population Density in Local Labour Market Regions in Sweden 2000



If we explore the relationship between value added per square kilometre and population density, excluding the four regions with the highest population density, we find that the distribution appears to be more differentiated. This is shown in Figure 5.3 that can be compared to Figure 5.2. Figure 5.3 shows that there are a number of regions that have very low value added per square kilometre, and that several of these regions also have a low population density.

**Figure 5.3** Value Added per Square Kilometre and Population Density in Local Labour Market Regions in Sweden 2000 (Excluding the four regions with highest density)



In Figure 5.4 below the relationship between value added per employee and the share of the labour force with longer higher education in local labour markets is illustrated. The regional share of the labour force with educational level of at least three years of university or college studies is used as a measure of high education in this case. It is obvious that there is a positive relationship between value added per employee and regional share of labour force with longer higher education.

**Figure 5.4** Value Added per Employee and Share of the Labour Force with Longer Higher Education in Local Labour Market Regions in Sweden 2000

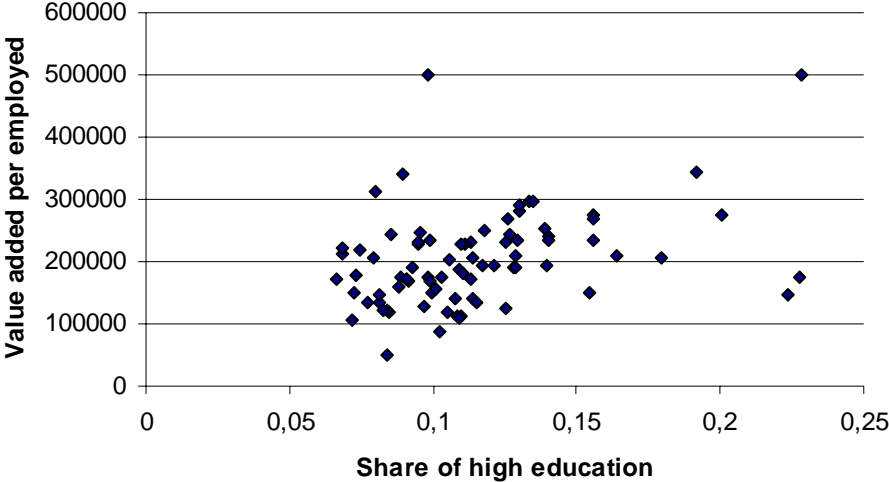
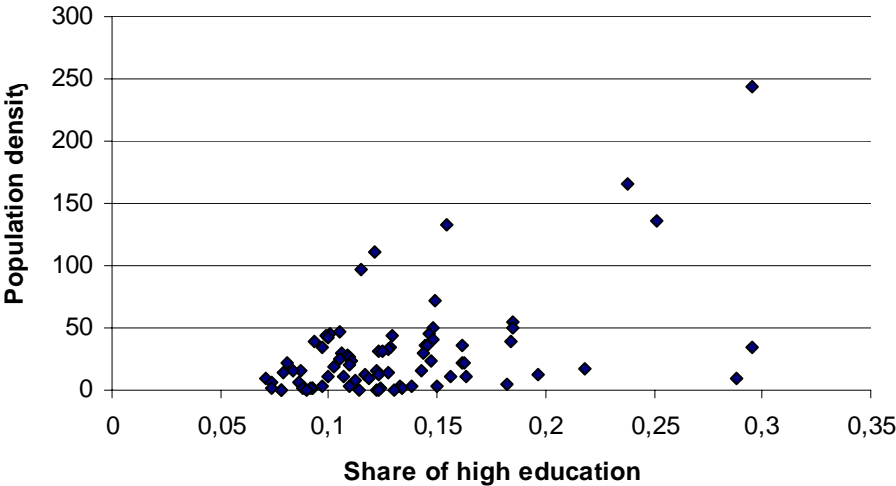


Figure 5.5 shows how the regional population density and the regional share of labour force with a longer higher education correlate. Again we find a positive relationship between the two variables.

**Figure 5.5** Population Density and Share of the Labour Force with Longer Higher Education in Local Labour Markets in Sweden 2000



From these descriptive statistics we can conclude that there is a positive relation between output-performance measured as value added per employee or per square kilometre and regional population density as well as regional share of labour force with longer higher education.

## 6. Empirical analysis

In a first cross section we estimate a model that is a variation of the model presented above in Equation 3.10. The analysis is made on Swedish data for the year 2000. Gross regional product/square kilometre in each municipality  $r$  is the dependent variable. The share of the labour force in each municipality  $r$  with longer higher education is an independent variable together with intra-municipal, intra-regional and interregional accessibility to population for each municipality  $r$ . In this way the spatial structure of the Swedish economy is captured and we are able to analyse the relative importance of access to markets and labour in neighbour municipalities as well as in more distant regions. Accessibility to population can be seen as a crude measure of the accessibility to labour force but it also accounts for the market potential effects. All values are logarithms, which mean that the estimated coefficients can be interpreted as elasticities.

$$\ln(\text{GRP}/\text{capita}_r) = \alpha + \beta_1 \ln H_r + \beta_2 \ln a_r^{IP} + \beta_3 \ln a_r^{IIP} + \beta_4 \ln a_r^{IIIP} + \varepsilon \quad (6.1)$$

where  $H_r = (h_r/100 - h_r)$  and  $h_r$  is equal to the share of the labour force in per cent with a long university education (three years or more),  $a_r^{IP}$  is intra-municipal accessibility to population in municipality  $r$ ,  $a_r^{IIP}$  is intra-regional accessibility to population in municipality  $r$ ,  $a_r^{IIIP}$  is interregional accessibility to population in municipality  $r$ , and  $\varepsilon$  is an error-term which is supposed to have a normal distribution. An advantage with this specification based upon accessibilities is that it takes care of the problems with spatial auto-correlation.

The result of the OLS cross-section analysis for Swedish municipalities is presented in Table 6.1 below. The analysis shows that a local labour force with a longer higher education and a high intra-municipal accessibility to population are the two most significant variables explaining

regional GDP per square kilometre. Access to markets and labour outside the municipality is not significant on the 5 percent level. The results from the cross-section analysis correspond very well with the results presented by Baptista (2003) for the UK economy. The estimation of our model for the Swedish economy yields a substantial higher level of goodness of fit compared to the study by Baptista. In our case we receive an adjusted  $R^2$  of 88 percent, compared 18-25 for his study of the UK economy.

**Table 6.1** Regional GDP per Square Kilometre Explained by Population Density and Share of the Labour Force with Longer Higher Education. Cross Section for Swedish Municipalities 2000. OLS-estimate

Independent Variable	$\beta$ -coeff.	Std. Errors	t-value
Constant	1.97	0.36	5.51
Share of the Labour Force with Longer Higher Education	0.77	0.14	5.59
Intra-municipal Accessibility to Population	0.70	0.04	17.70
Intra-regional Accessibility to Population	-0.002	0.02	-0.08
Inter-regional Accessibility to Population	-0.05	0.04	-1.49

$R^2$ -adj=0.88, n=288.

In a next step we continue with a panel data analysis using Swedish data for the years 1997-00. First we perform our study without taking accessibility to population outside the municipalities into account. This implies that we estimate our model for the 288 municipalities using only two explanatory variables: the share of labour force in each municipality with longer higher education and the intra-municipal accessibility to population. Again all variables are logarithmic, and can be interpreted as elasticities.



According to the test statistics we should use a model with our independent variables, individual- and time-effects. The Lagrange multiplier test with respect to a classical model that only includes our independent variables favours the fixed effects or the random effects model over the classical model. The Hausman-test for fixed versus random effects yields a value of 2.53, and, hence, we should use a random effects approach. We estimate our model using an FGLS-procedure and the results are presented in Table 6.2.

**Table 6.2** Regional GDP per Square Kilometre Explained by Intra-municipal Accessibility to Population and the Share of the Labour Force with Higher Education. Panel Data for Swedish Municipalities 1997-2000

<b>Independent variables</b>	<b><math>\beta</math>-coeff.</b>	<b>Std. Errors</b>	<b>P-value</b>
Constant	-1.63	0.14	0.00
Share of the Labour Force with Higher Education	0.91	0.44	0.04
Intra-municipal Accessibility to Population	1.03	0.16	0.00

$R^2$ -adj=0.94, n=1152.

From the results presented in Table 6.2 we find that the elasticities for both intra-municipal accessibility to population and the share of the local labour force with a longer higher education yields estimates around unity (higher education is slightly less). The estimates are all significant on the 5 percent level. Again the estimation has a high level of goodness of fit, with an adjusted  $R^2$  of 0.94. From this we can conclude that intra-municipal accessibility to population has a significant impact on the local productivity, as well as the educational level of the local labour force. The importance of these two variables appears to be more substantial for the Swedish economy than for the UK (compare with Baptista, 2003).

Continuing our analysis we also do a panel estimation using the model (6.1). Again data for the 288 Swedish municipalities for the period 1997-2000 is used. According to our descriptive statistics we expect heteroscedasticity to be present. In order to correct for this we apply a White-heteroscedasticity corrected co-variance matrix. The test statistics indicate that we should use a model that includes our independent variables as well as individual effects. We do not include time effects since the observation period is so short and because the period covers a recovery phase of the business cycle. The Hausman test for fixed versus random effects yielded a value of 0.05 and, hence, we decided to use a random effects approach. The model was estimated using a FGLS procedure.

However, in order to study the presence of different regimes in different types of municipalities, we have classified all municipalities into three different groups. This classification has earlier been used by Andersson & Klaesson (2003). First, the largest municipality in all the 81 local labour market regions (LLMRs)<sup>6</sup> represent one group as central places of the highest rank in their respective regions. Second, other municipalities in large labour market regions with a population larger than 100 000 make up the second group. This group contains 138 municipalities. Third, other municipalities in small labour market regions, i.e. labour market regions with a population less than 100.000 make up the third group. This group consists of 69 municipalities. The estimation of the model for each of this three types of municipalities yielded the results presented in Table 6.3.

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<sup>6</sup> 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 6.3** Regional GDP per Square Kilometre Explained by Accessibility to Population and the Share of the Labour Force with Longer Higher Education. Panel Data for Swedish Municipalities 1997-2000.

Independent variables	Largest municipality in all LLMRs	Other municipalities in large LLMRs	Other municipalities in small LLMRs
Constant	<b>1.52</b> (9.3)	<b>0.41</b> (2.0)	<b>0.18</b> (3.7)
Share of the labour force with higher education	<b>0.49</b> (10.7)	<b>0.51</b> (12.7)	<b>0.39</b> (7.1)
Intra-municipal accessibility to population	<b>0.54</b> (13.1)	<b>0.18</b> (2.7)	<b>0.48</b> (6.9)
Intra-regional accessibility to population	0.22 (0.1)	<b>0.46</b> (11.6)	0.41 (0.9)
Inter-regional accessibility to population	0.25 (0.6)	<b>0.12</b> (2.3)	0.52 (1.0)
R-squared	0.90	0.78	0.87
Number of observations	324	552	276

$\beta$  /Standard error within brackets. Bold figures = significance at the 95 %-level

R<sup>2</sup>-adj=0.88, n=288.

When we correct for heteroscedasticity and also include variables that reflect the spatial structure we can make several important observations. First, we find that the model is able to explain 78-90 per cent of the variation in the dependent variable in the three regressions in Table 6.3. Second, all significant variables have positive signs, as expected. Third, the variable share of the labour force with a higher longer education is significant in all three cases but is more important for the central municipality in each local labour market region and for municipalities in large labour market regions, compared to municipalities in small labour market regions.

It is most interesting to analyse the results for the three variables revealing the spatial structure, i.e. intra-municipal, intra-regional and inter-regional accessibility to population. The value added per square kilometre in the largest municipalities in each local labour market region is only

significantly influenced by the intra-municipal accessibility to population. Intra-regional and inter-regional accessibility to population show no significant influence. Our interpretation is that municipalities of this type are to a high-extent self-contained and thus dependent only on their own resource base and their own purchasing power.

The value added per square kilometre in other municipalities located in large local labour markets is in particular dependent upon intra-regional accessibility to population even if intra-municipal and inter-regional accessibility to population also have a significant influence. Our interpretation is that municipalities in this group to a substantial degree benefit from being close to a large central municipality, which serves as a source for resources and purchasing power.

The role of large central municipalities as sources of resources and purchasing power becomes even clearer when we compare with the results for other municipalities in small local labour market regions. Here intra-municipal accessibility to population has a significant influence on value added per square kilometre but the influence of the two other accessibilities is insignificant. This group of municipalities have to rely on their own base of resources and purchasing power and get little help from outside. For this group of municipalities will investments in intra-regional and inter-regional infrastructure that reduces travel times and thus improves accessibility have little or no effect on value added per square kilometre.

## **7. Conclusions and suggestions for future research**

Regional and local externalities that provide fundamentals for increasing returns have a most significant role in the Swedish economy. In this study we find that the share of the labour force with a longer higher education (at least three years of college or university study) and accessibility to population as a measure of population density explains very much of the variation of gross regional product per square kilometre across municipalities in Sweden.

In the study we use cross section as well as panel data estimations, which enable us to compare different approaches. We also account for spatial structure and analyse how accessibility to labour and markets in neighbour municipalities as well as the rest of the Swedish economy have influence on the local value added creation per square kilometre. Our conclusion is that the local conditions within the municipalities are most important explaining the performance. Accessibility to labour and markets outside the local market is in general of less importance, which means that

the fundamental local environment that generates externalities is most important for the performance of the local economy. This highlights the importance of conditions that supports increasing returns to scale that is generated by the local and regional economy.

Comparing the results from for example the study made by Baptista (2003) we find that the panel data approach is preferable, since estimations otherwise seem to be sensitive for the selection of year for cross section studies. When we estimate our model in a similar way as Baptista we receive similar results. However, when we correct for heteroscedasticity, use a more detailed representation of the spatial structure, and classify the municipalities into homogenous functional groups the results change significantly. Only for other municipalities in large local labour market regions do we get a significant influences on value added per square kilometre from intra-regional and inter-regional accessibility to population.

This study has implications with respect to higher education and investments in infrastructure for passenger transport. Different types of municipalities differ significantly to what extent that various types of transport infrastructure investments affect value added per square kilometre. In the central municipalities in each labour market region and in other municipalities in small local labour market regions it seems as it is only the local infrastructure that matters. Other municipalities in large local labour market regions should give priority to intra-regional infrastructure but in general be positive to the improvement of all types of transport infrastructure. Higher education and recruitment of labour with longer higher education is an important policy objective in all types of municipalities.

We see several prospects for future research. It would, for example, be interesting to analyse how other performance variables could be analysed at the municipal level using measures of accessibility as independent variables. One could also test other types of classification of municipalities.

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