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Accessibility: a useful analytical and empirical tool in spatial economics – experiences from Sweden

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Abstract:

Accessibility has for many years been a widely used tool in transportation research. Many definitions have been suggested and researchers have constructed numerous mathematical formulations to measure its value to be able to evaluate the relationships between the nature of the transport systems and the patterns of land use. Such correlations have been used especially in assessing existing transport systems and forecasting their performance to provide decision-makers with ideas about the need for investments in the transport systems. However, accessibility measures can be regarded as the spatial counterparts of discounting. The measures represent the spatial distribution of economic agents and their activities in a simple way that imposes a very clear structure upon the relationship between these agents and their activities and their environment. Various frictional effects arising from geographical distance between economic agents determine their interaction options, i.e., their options to trade, to cooperate, to learn, to commute, etc. Observing that the time sensitivities of the economic agents vary between different spatial scales (and between different economic activities) we may impose a spatial structure (e.g. local, intraregional, interregional and international), which offers opportunities to define variables in such a way that spatial dependencies can be accommodated. These newly defined variables can then be used in empirical explanations of various spatial phenomena, such as patent output, new firm formation, the emergence of new export products, and economic growth in different spatial units. We will in this paper against this background show that accessibility is an underused analytical and empirical tool in regional science with an underestimated potential. The paper contains several empirical examples where the accessibility concept has been used in previous research. These empirical studies are carried out in a Swedish context and show the applicability of the accessibility method. However, it is a general method and there is no reason why the method does not apply also for other countries.

JEL Codes: C21, R11, R12, R23, R58

Key words: Accessibility, spatial models, spatial dependence, local labour markets, spillover effects, regional development.

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1. Introduction

The so-called "1st law of geography" (Tobler, 1970) states that everything in space is related but that the relatedness between spatial units decreases with distance. This spatial dependence between spatial units should be perceived as a generic occurrence that is subject to distance-related friction phenomena. Spatial dependence implies, e.g., that activities in one spatial unit have an effect on the activities in other regions but that the strength of this effect diminishes with distance. For example, spatial externalities that are mediated via the labour market depend on the interaction in the labour market – a market in which mobility is severely limited by the distance between spatial units. However, the spatial dependence between different spatial units also depends on the frequency of various types of interaction between these spatial units. That interaction decreases with distance is an axiomatic statement in regional science (cf., Beckmann, 2000). The accessibility approach offers an opportunity to develop measures that can catch the effect of distance-related frictions and thus how the strength of spatial dependencies diminishes with distance. Or, with other words, accessibility measures approximate the potential for interaction among spatial units (Weibull, 1980). Accessibility measures represent spatial discounting procedures that relate to central concepts in spatial interaction theory.

The accessibility concept has a long history in both regional science and transport economics. According to Martellato, Nijkamp & Reggiani (1998), Hansen (1959) provided one of the first for the use of an "accessibility theory" and defined accessibility as the potential of opportunities for interaction. Baradaran & Ramjerdi (2001) note that this way of defining accessibility is closely associated with gravity models based on the interaction of masses.

The purpose of this paper is to show that accessibility is a useful analytical and empirical tool in spatial economics with an underestimated potential. We will not discuss alternative definitions and measures of accessibility and we will not try to review the general accessibility literature. There are already a substantial number of excellent reviews available (see, e.g., Pirie, 1979; Handy & Niemayer, 1997; Reggiani, 1998). What we will do is to illustrate how accessibility measures can be used in a spatial context to explain patent output regional economic growth, new firm formation, the emergence of new export products, etc. We will focus on empirical examples conducted in a Swedish context. The municipalities in Sweden are divided into local labour market regions[3] and this will affect how the accessibility measure is designed and used.

The paper is structured as follows: Section 2 introduces the accessibility concept and shows how it can be used to incorporate and explain spatial dependencies that may occur within regions and across regional borders. The section also demonstrates that an accessibility representation of explanatory variables depict the network nature of spatial interaction, such that spatial dependence is actually modelled. Section 3 illustrates different settings where the accessibility concept can be or have been used in previous research. Section 4 concludes.

[3] The concept of local labour market region is closely associated with the concept of a functional urban region (cf. Cheshire & Gordon, 1998).

2. Spatial entities, time distances and accessibility measures[4]

The accessibility model presented in this paper starts with the notion that a country can be divided into a number of labour market regions, each consisting of a number of municipalities between which the commuting intensity is high. In Sweden the delimitation of local labour markets is done in two steps:

1. *Determination of local centers*. Two conditions have to be fulfilled in order for a municipality to be a local center.
    a. At least 80 percent of the employed in a municipality have to have their working place in the municipality.
    b. The number of commuters of a municipality to another municipality has to be below 7.5 percent of the employed working force.
2. *Determination of the remaining municipalities' belonging*. The rest of the municipalities are connected directly or indirectly to the local centers that receive the largest number of commuters from these municipalities.

The number of local labour markets in Sweden has diminished over time, from 187 in 1970 to 79 in 2006. Consequently the average size of a local labor market has increased. Local labour markets can be found also in other countries. There are 15 countries within EU that use labour market areas. Usually these are built on the basis of municipalities. However, in Germany a level above municipalities is used and in Great Britain a level below the municipality level is used.

It is also possible to divide each municipality into a number of zones. From such a starting point we can imagine that it is meaningful to measure the accessibility between zones within a municipality, between municipalities within a local labour market region and between a municipality in a given labour market region and all other municipalities in all other labour market regions in the country. In this manner it is possible to characterize the overall interaction patterns among spatial units, which naturally vary between different geographical scales and types of spatial units.

Accessibility can in this connection be thought of as a proximity measure to something desired (or something disliked for that matter). Thus, there are strong reasons to associate accessibility with preference or choice theory. Accessibility can be interpreted in several, partly overlapping ways (Weibull, 1980): i) nearness, ii) proximity, iii) the ease of spatial interaction, iv) potential of opportunities of interaction, and v) potentially of contacts with activities (including supply and demand). Here the focus will be on interpretation iv) and how this interpretation can be related to preferences as specified in random choice theory.

Assume that an individual faces *s* choices, e.g. commuting links. We can then define an underlying latent variable U_{kl}^{*} to denote the level of indirect utility associated with the choice to commute from municipality *k* to municipality *l*. The observed variables U_{kl} are defined as

$$U_{kl} = 1 \text{ if } U_{kl}^{*} = Max(U_{k1}^{*}, U_{k2}^{*}, \dots, U_{ks}^{*}) \qquad (1)$$
$$U_{kl} = 0 \text{ otherwise}$$

[4] This section builds upon Johansson, Klaesson & Olsson (2002) and Andersson & Gråsjö (2009).

Let us write $U_{kl}^{*} = V_{kl}(X_{kl}) + \varepsilon_{kl}$, where X_{kl} is a vector of attributes for choosing commuting link (k, l) and ε_{kl} is an extreme value distributed error term. Then it is possible to derive[5] the following probability that an individual in municipality k will choose the commuting link (k, l):[6]

$$P_{kl} = Prob(U_{kl} = 1|X) = exp\{V_{kl}\}/\sum_s exp\{V_{ks}\} \quad (2)$$

This formulation implies that the probability of choosing a specific link follows a Poisson distribution. In this case, the numerator in (2) represents the preference value of the labour market in municipality l, and the denominator the sum of such values over all municipalities s. Thus, the probability of commuting on the link (k, l) is equal to the normalized preference value and P_{kl} can be interpreted as a ratio between the potential preference value of link (k, l) and the sum of preference values given by $\sum_s exp\{V_{ks}\}$.

Assume the following specification of the utility function

$$V_{kl} = a_l - \gamma c_{kl} - \mu t_{kl} \quad (3)$$

where a_l represents an attractor factor in municipality l, c_{kl} denotes the commuting costs from k to l and t_{kl} is the time distance[7] between the municipalities. Let us now introduce two more assumptions: i) $a_l = lnA_l$, where A_l represents the total number of jobs in l and ii) $c_{kl} = \mu_c t_{kl}$, which implies that the commuting costs are proportional to the time distance on a link t_{kl}. With the use of these two assumptions the denominator in (2) can be expressed as:[8]

$$T_k^A = \sum_s exp\{-\lambda t_{ks}\}A_s \quad (4)$$

which is a standard measure of job accessibility in a municipality k, where the time sensitivity parameter $\lambda = (\gamma\mu_c + \mu)$. Based upon this formulation, it is now possible to define other accessibility measures, where the number of jobs A_s is substituted with other measures, such as the supply of household services, the supply of business services, the supply of labour, etc. in municipality s. Naturally, the opportunities are specific for each group of actors in the economy.

We are now in a position to ask to what extent interaction between zones within a municipality is different from interaction between municipalities in the same labour market region? Furthermore, is intra-regional interaction different from extra-regional interaction? The typical time distances for the three types of interaction in Sweden indicate that there may be a qualitative difference. For interaction between zones within municipalities the average time distance by car varies in the range between 8-

[5] See, e.g. Maddala (1983) or Train (1986).

[6] We use commuting between municipalities as an example but we could have used any type of interaction as our example. The conclusions are general.

[7] Researchers often measure distance by the geographical distance, but a better way to measure it is to use the time it takes to travel between different locations (Beckmann, 2000). Time distance is e.g., crucial for the frequency of interregional business trips in Sweden (Hugosson & Johansson, 2001; Johansson, Klaesson & Olsson, 2002).

[8] The negative exponential function emerges directly from an entropy maximizing framework with origin, destination and cost constraints (cf., Smith, 1978; Wilson, 2000).

15 minutes. Inside a labour market region the average time distance by car has an interval of 20-50 minutes. Extra-regional time distances are, on average, longer than 60 minutes by car.

Given these travel time distances, it is natural to assume the frequency of intra-municipality interactions between agents is much higher than the frequency of inter-municipality interactions, since mobility and interaction is time-consuming and also consumes other resources. Within the framework presented above this assumption can be taken care of by allowing the time-sensitivity parameter λ to be different for interactions inside a municipality than for interactions between municipalities. However, Johansson, Klaesson & Olsson (2002) have instead specified the attractiveness of the destination supply as different for intra- and extra-municipality interactions. They accomplish this as follows:

$$V_{kk} = ln\alpha_1 A_k - \lambda t_{kk} \quad \text{and}$$
$$V_{ks} = ln\alpha_2 A_s - \lambda t_{ks} \quad \text{for } s \neq k$$

where the first systemic preference indicator refers to intra-municipal interactions and the second to extra-municipal interactions. These indicators generate in a natural way a compound measure T_k^A of accessibility of municipality k:

$$T_k^A = \alpha_1 T_k^{AI} + \alpha_2 T_k^{AE}$$

where

$$T_k^{AI} = A_k exp\{-\lambda t_{kk}\} \text{ and}$$
$$T_k^{AE} = \textstyle\sum_{s \neq k} A_s \, exp\{-\lambda t_{rk}\}$$

represent intra-municipal and extra-municipal accessibility, respectively, and where $s \neq k$ is the set of municipalities except k.

Furthermore, it is possible to make a distinction between interactions that may occur between municipalities within the labour market region and accessibilities to all municipalities outside the region. If we also take into account the different time sensitivities three types of preference indicators can be identified:

$$V_{kk} = ln\alpha_1 A_k - \lambda_k t_{kk},$$
$$V_{ks}^R = ln\alpha_2 A_s - \lambda_R t_{ks} \quad \text{for } s \in R \text{ and}$$
$$V_{ks}^E = ln\alpha_3 A_s - \lambda_E t_{ks} \quad \text{for } s \in E$$

The compound measure T_k^A of accessibility of municipality k is the given by:

$$T_k^A = \alpha_1 T_k^{AI} + \alpha_2 T_k^{AR} + \alpha_3 T_k^{AE}$$

where T_k^{AI} represents the intra-municipal accessibility of municipality k, T_k^{AR} represents the intra-regional accessibility of municipality k, i.e. the accessibility to the other municipalities in the same labour market region R, and T_k^{AE} represents the extra-regional accessibility of municipality k, i.e. the accessibility to all municipalities outside the labour market region R.[9] Johansson, Klaesson & Olsson (2003) illustrate that

[9] The accessibility measures used here satisfies criteria of consistency and meaningfulness (Weibull, 1976) and has a clear coupling to spatial interaction theory.

the time sensitivities for the case of Sweden follow a non-linear form such that $\lambda_k < \lambda_E < \lambda_R$. Obviously, any accessibility for a municipality can be decomposed this way.

Potential statistical problems associated with dependence among observations in cross-sectional data are extensively treated in spatial econometrics literature (e.g. Anselin, 1988; and Anselin & Florax, 1995; LeSage and Pace, 2009; Elhorst 2010). A presence of any kind of spatial dependence can invalidate regression results. In the case of spatial error autocorrelation, OLS parameter estimates are inefficient and in presence of spatial lag dependence parameters become biased and inconsistent (Anselin, 1988). Moreover, a fundamental problem in applied spatial econometrics concerns the specification of the spatial interaction structure, i.e. the structure of the spatial weight matrix, (Florax & Rey, 1995). In the context of the present paper, the inputs in other spatial units should optimally be spatially discounted in a way that reflects the distance sensitiveness of the effects (or externalities) involved. With respect to the spatial discounting procedure, this paper advocates the use of accessibility as a measure of potential opportunities. Throughout the paper, the spatial weight matrix is based on the concept of accessibility as a measure of potential of opportunities.

Using the taxonomy by Anselin (2003), Andersson & Gråsjö (2009) investigate how the inclusion of spatially discounted variables (i.e. accessibility variables) on the 'right-hand-side' (RHS) in empirical spatial models affects the extent of spatial autocorrelation. The basic proposition is that the inclusion of inputs external to the spatial observation in question as a separate variable reveals spatial dependence via the parameter estimate. One of the advantages of this method is that it allows for a direct interpretation. The authors also test to what extent significance of the estimated parameters of the spatially discounted explanatory variables can be interpreted as evidence of spatial dependence. Additionally, they advocate the use of the accessibility concept for spatial weights. Monte Carlo Simulations show that the coefficient estimates of the accessibility variables are significantly different from zero. The rejection frequency of the three typical tests, Moran's I, LM-lag and LM-err, is significantly reduced, when accessibility variables are included in the model. The authors stress that when the coefficient estimates of the accessibility variables are statistically significant, it suggests that problems of spatial autocorrelation are significantly reduced. Significance of the accessibility variables can be interpreted as spatial dependence.

The accessibility approach is of great interest for policy makers, since it makes it clear that policy makers can get a higher accessibility by two different measures. Either they can improve the transport infrastructure and public transport to reduce travel times or they can increase the potentials in different municipalities. However, the accessibility approach also makes it obvious that it is of great importance which transports links that are improved, and where the increased potentials are located.

The accessibility variables can be calculated for different kinds of opportunities and used in empirical explanations of various spatial phenomena. The following section will illustrate how, for example, patent output, new firm formation, diversity of export products and economic growth in different spatial units have been modelled with the use of accessibility variables.

3. The accessibility approach in different empirical settings

The accessibility approach can be used in various situations. This section demonstrates its applicability and provides the reader with Swedish examples where the accessibility concept has been used in previous research concerning spatial economics.

3.1 Knowledge production functions

An accessibility approach to the analysis of knowledge spillovers has important implications for public policy. Because knowledge spillovers represent a positive externality and thus, a disincentive for a firm to do R&D and/or to produce at a socially optimal level, governments to encourage R&D and/or production might use subsidies and other measures such as patent laws. The framework presented in Karlsson & Manduchi (2001) offers a new perspective when discussing technology policy. It is obvious that technology policy must be discussed within this broader framework and not limited to issues regarding R&D and higher education. Also infrastructure policies involving local as well as intra- and interregional communication and transportation networks must be brought up on the agenda.

It is also obvious that simple solutions such as "broadband Internet access for everyone" will not do the trick. There is a strong need to consider the complementarities between, on the one hand, communication and transportation networks, and, on the other hand, between infrastructure investments and investments in R&D and higher education. One must in this connection also acknowledge that policies aiming at increasing knowledge spillovers to stimulate, for example, cluster formation may reduce the private incentives for doing R&D, and, hence, demand either extended legal protection of inventions or larger public investments in or subsidies for R&D.

To model the influence of knowledge spillovers on knowledge production Griliches (1979) introduced the concept of a knowledge production function. The knowledge production function links the inputs in the innovation process to innovative outputs. According to Griliches, the most decisive innovative input is new economic knowledge, and the greatest source that generates new economic knowledge is generally considered to be R&D. Jaffe (1989), Feldman (1994 a & b) and Audretsch & Feldman (1996) modified the knowledge production function approach to a model specified for spatial and product dimensions.

The traditional knowledge production function approach tends to be used at an aggregated level and it does not consider the knowledge spillovers made possible by knowledge accessibility as defined here. Machlup (1980) defined knowledge production as any activity through which someone in a firm or an organisation learns of something he or she had not known before, even if others knew about it. Knowledge production can involve both the creation of new knowledge and the search for new understanding from old knowledge. Knowledge production implicitly presumes the exchange of knowledge among persons. The formation of something new demands the amalgation of different concepts and different pieces of knowledge. Such a creative feature of the process of knowledge exchange can be described as a form of dynamic synergy. Hence, knowledge production activities demand a high degree of ac-

cessibility to other knowledgeable persons. We argue here that the effect of knowledge spillovers on the output from R&D carried through within an industry or within specialised R&D institutions, i.e. universities and similar institutions also must be considered. For the specialised R&D-sector we assume that the important knowledge spillovers come on the one hand from within the sector and on the other hand from other regions.

The link between proximity and innovation has been dwelled upon extensively in the literature. A regional economic milieu characterized by proximity between relevant actors is maintained to be suitable for establishing and maintaining successful regional innovation system. Andersson & Karlsson (2004) propose that the relevant link to be studied is rather that between accessibility and innovation. The authors argue that although accessibility is a key factor in facilitating the processes to be important for innovations, the relationship is surprisingly unexploited.

Andersson, & Ejermo (2002) remark that knowledge production function (KPF) approaches to estimation of knowledge flows in regions have come under attack not to open the 'black box' of knowledge creation and that it has been questioned whether spillovers really are the key determinants of knowledge diffusion rather than market mechanisms. Nonetheless, the authors claim that KPF approaches can be useful to get a rough picture of the aggregate magnitude of agglomeration effects pertaining to knowledge. Within a KPF framework, they study the relationship between the amount of R&D of firms and universities and the amount of patent applications for Swedish functional region. Interregional knowledge flows are weighted by the frictional effect of time distance. However, the analysis was not conducted within a proper spatial econometric framework and the authors therefore refrain from drawing any precise conclusions of the estimates.

In their 2004 paper Andersson & Ejermo (2004) attempt to explain knowledge production in Swedish functional regions as measured by the number of patent applications applying an accessibility approach. Recognizing that technological opportunity differs across sectors, a sectoral analysis is conducted. The KPF approach is applied in order to relate patent applications to a number of relevant knowledge sources. Beside R&D accessibility variable, the stock of patent applications is included as an explanatory variable in the analysis. The results show that the patent stock of a region contains much of the information needed in order to explain current patenting activity. This is interpreted as suggesting strong effects of path dependence.

Andersson & Ejermo (2005) analyse the innovative performance of 130 Swedish corporations during 1993-94 using an accessibility-based knowledge production function approach in line with that presented above. The number of patents per corporation is explained as a function of the accessibility to internal and external knowledge sources of each corporation. Their results show that there is a positive relationship between the innovativeness of a corporation and its accessibility to university researchers within regions where own research groups are located. The size of the R&D staff of the corporation seems to be the most important internal factor. There is no indication in the results that intra-regional accessibility to other corporations' research is important for a corporation's innovativeness.

Ejermo & Gråsjö (2008) examine the effects of regional R&D on patenting for Sweden within an accessibility framework. They use two measures of patenting: number of patents granted per capita and a composite of quality-adjusted patents which they regard as an innovation indicator, respectively. Two important conclusions emerge. First, they find that the specification where innovations per capita is used as a dependent variable performs much better than with granted patents per capita for capturing relationships with regional R&D. Secondly, accessibility to inter-regional R&D do not affect innovation significantly, which suggests that effects are regionally bounded. This implies that studies of the R&D-innovation relationship are plagued by misspecification, since studies tend to show that R&D-effects diffuse to other regions. This is also the case in their study; the inter-regional effects are an important factor for granted patents. In view of these results their recommendation is to use quality-adjusted patents for regional innovation studies rather than patent grants.

The extent to which accessibility to R&D can explain patent production is further analysed by Gråsjö (2009). A knowledge production function is estimated both on aggregated level and for different industrial sectors. The output of the knowledge production is the number patent applications in Swedish municipalities from 1994 to 1999. The explanatory variables are expressed as accessibilities to university and company R&D at different special levels (local, intra-regional and inter-regional). A conclusion from the paper is that concentrated R&D investments in companies located in municipalities with a high patenting activity would not only gain the municipalities themselves, but also the patent production in other municipalities in the same functional region.

The purpose of the paper by Gråsjö (2012) is to analyze the effects of national and international knowledge flows on innovative activity (patent applications in Swedish municipalities). The knowledge resources applied, R&D investments and high valued imports, are expressed as accessibilities. The main results indicate that knowledge resources in a given municipality tend to have a positive effect on the innovative activity of another municipality, given that the municipalities belong to the same functional region. This result holds for both R&D investments and high valued import products

3.2 Regional productivity and growth

Knowledge flows not only influence knowledge production. They also have a direct effect on the output of an individual industry in a region. Common output measures used in empirical studies that deal with regional productivity and growth are change in value added, gross regional product and wage sum. Also other output measures like growth in population or employment can be found.

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. Karlsson & Pettersson (2005) make an empirical analysis using data for Swedish municipalities with the purpose to analyse the relationship between regional productivity measures and accessibility to educated labour. They find that local externalities for increasing returns are very important in the Swedish economy. Their estimated models indicate

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.

Using an accessibility-based hierarchy of municipalities, Andersson & Klaesson (2006) relate growth in these municipalities to intra-municipal, intra-regional and interregional accessibility. They explore the growth in (i) population, (ii) employment and (iii) commuting flows. The purpose of their study is to reveal systematic regularities in growth performance. Having established the overall pattern of change, they examine if the ICT service sectors follow or deviate from this pattern. Their results show that there are strong similarities between the growth of individual ICT service sectors and the overall growth of the economy. Furthermore, the overall pattern suggests that municipalities with larger initial market accessibilities grow faster. This supports the presence of self-strengthening cumulative processes and implies that the size-distribution of municipalities becomes more uneven over time

Also the paper by Andersson & Noseleit (2009) investigates Swedish employment growth. However, they extend previous analyses by examining the influence of regional start-ups in a sector on regional employment growth in the same sector and on other sectors. They find that knowledge-intensive start-ups seem to have larger effects on the regional economy. In particular, start-ups in high-end services have significant negative impacts on employment in other sectors but a positive long-run impact. This is consistent with the idea that start-ups are a vehicle for changes in the composition of regional industry.

Several studies have been conducted on Swedish data to analyse the relationship between R&D investments and regional economic growth (Andersson, Gråsjö & Karlsson, 2007; Andersson & Karlsson, 2007; Karlsson, Andersson & Gråsjö, 2008). 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. Strong evidences show that knowledge transfers to a high extent depend upon face-to-face interaction and the volume of knowledge flows depends upon the interaction possibilities at different spatial scales. It is meaningful to identify a number of such spatial scales based upon the character of the generalized spatial interaction costs. In particular, there are three spatial scales that are of special importance: (i) the local scale that allows several interactions a day, (ii) the intra-regional scale - the commuting scale - that allows for daily interaction, and (iii) the interregional scale that allows only for a limited number of planned interactions a month or a year. With the use of accessibility measures on these three scales it is possible to determine whether R&D-generated knowledge has a local, intra-regional and/or interregional impact on economic growth. Two results stand out from the studies: (i) The knowledge accessibility in a given period has a statistically significant effect on the growth in subsequent periods. (ii) The knowledge resources in a given municipality tend to have a positive effect on the growth of another municipality, conditional on the municipalities belonging to the same functional region. Thus, knowledge flows transcend municipal borders, but they tend to be bounded within functional regions.

Andersson, Gråsjö & Karlsson (2008) focus on the role of human capital for regional productivity (wage sum per employee). They argue that a localities position in a hierarchical spatial economic system is likely to alter the importance of the human capital in surrounding localities for its productivity level. The authors show that the relative importance of accessibility to external human capital for localities with a low position in a spatial hierarchy is significantly larger than for localities with a high position in the hierarchy.

It is well-known that wages tend to be higher in larger regions. This can be explained by the fact that regions have different industrial compositions and that average regional productivity differs among regions. Using a decomposition method, similar to shift-share, Klaesson & Larsson (2009) separate regional wage differences into an industrial composition component and productivity component. According to theory it is expected that productivity is higher in larger regions due to different kinds of economies of agglomeration. In addition, the diversity of sectors is more pronounced in larger regions compared to smaller regions. The authors use a market potential measure (accessibility to Gross Regional Product) for regional size a variable to explain regional differences in wages, productivity and industrial composition. Their results confirm that larger regions have higher wages, originating from higher productivity and more favourable industry composition.

Ejermo & Gråsjö (2011) explore the link between invention and innovation on the one hand and the level of economic activity and economic growth in Swedish regions by using patents granted and the quality of patents as indicators of invention and innovation respectively. Their results indicate that both types of measures are able to explain the level and the changing level of economic activity equally well. However, an important difference is that inventions have the strongest marginal effect in regions where economic activity is the highest. Innovations have similar marginal effects across regions with different economic activity. The authors' interpretation is that quality-adjusted patents sort out 'bad' from 'good' patents in a manner which reflect economic importance.

3.3 The relation between company and university R&D

The rapid globalization in recent years has created a radically new competitive situation for the rich industrialized countries. Newly industrialized countries and not least China have become more and more successful in penetrating the markets in the rich industrialized countries with increasingly more advanced export products. This has generated a discussion in the rich industrialized countries on how to meet this increased international competition. In some countries demands for various protective measures have been raised while in others the discussion has mainly focused on how to develop a competitive strategy mainly concentrating on making the own products more sophisticated by increasing their knowledge content. This is by no means an easy task since the direct product development is controlled to a high extent by multinational firms, which to an increasing degree are foreign owned. Governments mainly have to rely on indirect measures, such as increasing the volume of higher education and public, mainly university, R&D. This raises the question: how responsive is private industry to these kinds of indirect measures.

Against this background, Andersson, Gråsjö & Karlsson (2009) present a study with the purpose to analyse to what extent the location and the extent of higher education and university R&D, respectively, influence the location and the extent of industry R&D in Sweden using an accessibility approach. They develop a model for the location of R&D from the perspective of a multinational enterprise and show that the location of industry R&D in Sweden can be partly explained by the intra-municipal accessibility to students in higher education, while the accessibility to university R&D turned out to be insignificant.

Karlsson & Andersson (2009) claim that at the same time as we can observe strong tendencies of a globalisation of R&D, we also can observe a strong spatial clustering of R&D and related innovative activities. The standard explanation in the literature of the clustering of innovative activities is that such clusters offer external knowledge economies to innovative companies, since they are dependent upon knowledge flows and that knowledge flows are spatially bounded. There are two major performers of R&D: industry and universities. It seems rather straight-forward to assume that industrial R&D might be attracted to locate near research universities doing R&D in fields relevant to industry. The question is if it also works the other way around? Does industrial R&D function as an attractor for university R&D? It is possible to think of several reasons why university R&D may grow close to industry R&D. First of all political decision-makers may decide to start or expand university R&D at locations where industry already is doing R&D. Secondly, one can imagine that industry doing R&D in a region might use part of their R&D funds to finance university R&D. Thirdly, universities in regions with industrial R&D might find it easier to attract R&D funds from national and international sources due to co-operation with industry.

Obviously, not all types of university R&D attract industrial R&D. The above implies that there are behavioural relationships between industrial R&D and university R&D and vice versa. However, the literature contains few studies dealing with this problem. Most studies have concentrated on the one-directional effect from university R&D to industrial R&D and the outputs of industrial R&D in most cases measured in terms of the number of patents and neglected the possible mutual interaction. However, if there is a mutual interaction between university and industry R&D, and if there are knowledge externalities involved, then it is possible as Karlsson & Andersson (2009) do to develop a dynamic explanation to the clustering of innovative activities based on positive feedback loops. This implies strong tendencies to path dependency and that policy initiatives to transfer non-innovative regions to innovative regions would have small chances to succeed. Karlsson & Andersson (2009) show that the location of industrial R&D is sensitive to the accessibility of university R&D, and that location of university R&D is sensitive to the accessibility of industrial R&D.

3.4 Exports

The relation between export competitiveness and knowledge at both the nation and the firm level is explored in several empirical studies (Fagerberg, 1988; Greenhalgh et al, 1994; Wakelin, 1998; Basile, 2001) The general concluding results from these studies are that innovation, measured by proxies of input (e.g. R&D expenditure) or of output (e.g. number of patents) is an important factor in explaining export performance. However, what is lacking in the studies at nation and firm level is the

role of geographical proximity in facilitating the transmission and the absorption of technological and scientific knowledge.

Johansson & Karlsson (2007) examine the influence of accessibility to R&D on the regional diversity in Swedish export. They argue that the effects of R&D on regional export performance are reflected by the size of the export base rather than by the export volumes. The empirical analysis focus on three different indicators of export diversity; the number of exported goods, the number of exporting firms and the number of export destinations. The results suggest that the three indicators of regional export diversity are positively affected by the intra-regional accessibility to company R&D in commodity groups that have a relatively high R&D-intensity in production. Inter-regional accessibility to company R&D has significant positive impacts on the number of export goods and the number of export destinations also in less R&D-intensive industries. In the case of university R&D, the empirical results are weaker, in particular in the case of intra-regional accessibility. Yet, the inter-regional accessibility to university R&D has a significant positive impact on the number of export goods and the number of export destinations in the majority of commodity groups.

The extent to which accessibility to R&D and human capital can explain regional exports is also analysed by Gråsjö (2008). The author performs a comparison between a volume measure (total export value) and a diversity measure (number of high value export products) in Swedish municipalities. The results in Gråsjö (2008) indicate that accessibility to human capital has the greatest positive effects. The value of exported products is mainly affected by local accessibility to human capital (and company R&D). The intra- and inter-regional accessibilities play a more important role, when the number of high valued export products in Swedish municipalities is the output.

Bjerke & Karlsson (2009), on the other hand, focus on the role that metropolitan regions play for the renewal of the export base in the non-metropolitan regions in a small country. In smaller countries, the non-metropolitan regions are to a large extent linked together with the metropolitan regions through various networks. The national infrastructure and transport networks are often organised with the metropolitan region as the central hub. This creates a number of dependencies between the metropolitan region and the non-metropolitan regions in a small country. The analytical part their paper can be divided into three main parts: i) the role of the Stockholm metropolitan region for the renewal of the export base in the rest of Sweden between 1997 and 2003; ii) which non-metropolitan regions gain renewal of their export base; and iii) what factors can explain the spatial distribution of these gains. The results of the paper show that distance has little to do with the potential success of export products diffused from Stockholm. Instead, regional characteristics such as a large manufacturing sector, educational level, size of public and/or agricultural sector, and high intra-regional accessibility to producer services have a larger influential potential.

3.5 New firm formation

Several scholars have included accessibility-based measures in their analysis of factors determining new firm formation. Andersson & Hellerstedt (2009) study start-

ups in Knowledge Intensive Business Services (KIBS) across regions in Sweden. Their empirical analysis takes into account both supply- and demand-side factors. Supply-side variables reflect knowledge and information upon which a new firm can be established. Demand-side variables refer to market potential proxied by accessibility to regional wage sum. Controlling for the stock of potential entrepreneurs and the stock KIBS firms, they show that both supply- and demand-side factors influence KIBS start-up activity. Their results display that the presence of knowledge resources and accessibility to a large market are beneficiary conditions for KIBS start-ups.

Karlsson & Backman (2011) investigate the impact of human capital accessibility on new firm formation. The empirical analysis in the study is based on data on new firm formation at the municipality level in Sweden and accessibility to human capital, where carriers of human capital is defined as those individuals with at least three years of university education. The results indicate that intra-municipal accessibility to human capital has a positive impact on new firm formation in municipalities.

Accessibility-based measures to explain new firm formation are also used by Grek, Karlsson & Klaesson (2011). The authors' purpose is to explain the variations in entrepreneurship between regions of various sizes, and test the theoretical arguments on why large regions generally should generate more entrepreneurship. The results show that the market potential as measured by local and external accessibility to gross regional product (GRP) has a strong significant impact both on entry of new firms and on firm exit. For the primary sector and the manufacturing sector this impact is negative, while it for the ordinary service sector and the advanced service sector its positive. A high employment rate has a strong negative impact on firm entry in all sectors. This is in line with what one could expect as there are weaker incentives for individuals starting their own businesses in periods of a low unemployment rate. Furthermore, the presence of many small firms in different sectors has a strong positive significant impact on new firm formation. Also Andersson & Koster (2011) make use of accessibility to GRP as a measure for regional market potential. The paper analyses the persistence of start-up rates across Swedish regions. The authors find that start-up rates of a decade earlier are able to explain over 40 % of the variation in current start-up rates across regions.

Karlsson & Nyström (2011) investigate the role of accessibility to university and company R&D for new firm formation. Company R&D is assumed to contain a higher share of R&D directed towards generating technological knowledge. Hence, the accessibility to such R&D is expected to have a stronger influence on new firm formation than the accessibility to university R&D and this is also what the empirical results of the paper indicate. The authors also find that close knowledge interactions are more important for new firm formation than long-distance knowledge interactions. Accessibility to interregional company R&D has even a negative impact on new firm formation.

3.6 Regional interaction and diversity

A paper by Andersson & Klaesson (2009) analyses how a region's relative market-accessibility in a system (or hierarchy) of municipalities affects the extent of diversity.

In the theoretical part of the paper a model of municipal diversity in retail and durables is introduced. Using this model as a point of reference, the authors explore the relationship between market-size and diversity in Swedish regions. Three types of market-sizes are considered: (i) intra-municipal, (ii) intra-regional and (iii) extra-regional. They show that the relationships between diversity and the three types of market sizes differ between different types of municipalities in the hierarchy, implying that such a classification is warranted. One particular finding that corresponds to the agglomeration shadow-effects usually discussed in NEG-theories is that large municipalities gain from proximity to surrounding municipalities while small municipalities do not.

3.7 Location dynamics of firms

Andersson (2006) investigates the tendencies of co-location between producer services and manufacturing across Swedish functional regions using an accessibility-based approach. The employment in these industries is modelled simultaneously, i.e. the location of producer services is a function of the accessibility of manufacturing and vice versa. The assumption motivating the simultaneous approach is that manufacturing firms benefit from short-distance supply of producer services and service suppliers benefit from accessibility to customers among the manufacturing firms. The empirical results of the paper suggest that the location manufacturing employment can be explained by its accessibility to producer services. However, accessibility to manufacturing is not a statistically significant explanatory factor for the location of producer services.

Johansson & Klaesson (2011) consider the location dynamics of two categories of firms: contact-intensive producer-service suppliers and other firms. The authors argue that firms have random choice preferences and react in a non-linear way to time distances in their contact efforts. Hence, firms make their location decisions in response to local, intra-regional and interregional accessibility to market demand. The econometric analysis in the paper takes into account time distances between zones in urban areas as well as between urban areas in the same agglomeration and between urban areas in different agglomerations. This information is used in an econometric model that depicts for each urban region how the number of jobs in different sectors changes in response to the access to customers' purchasing power in the entire set of urban regions. The empirical results of the paper suggest that firms' location choices depend on local and intra-regional accessibility to market demand. Interregional accessibility is also of importance, but only for producer-service suppliers and not for other firms.

3.8 Labour mobility

Andersson & Thulin (2011) focus on inter-firm labour mobility. They study to what extent spatial employment density can explain inter-firm job-switching. The empirical results of the study show that employment density has a positive impact on the probability of job switching and that inter-firm labour mobility varies substantially across regions. Moreover, the likelihood that such switching is intra-regional is significantly higher if the employees operate in denser regions. The authors conclude

that higher rates of inter-firm labour mobility seem to be a probable mechanism behind the empirically verified productivity advantage of dense regions.

3.9 Summary of the empirical studies

As demonstrated, the accessibility concept can be used in numerous empirical settings. Whenever the theory suggests that inputs in locations outside the own location are assumed to have an impact on this location's output, but that such inter-locational effects diminishes with distance, the accessibility measure is a potential useful tool. The main research questions dealt with in this section are:
To what extent

- regional patent production is explained by accessibility to knowledge resources (mainly R&D, but also diversity of import products),
- regional productivity and growth (employment, wage sum, value added etc.) is affected by accessibility to knowledge resources (R&D, educated labour, patents) and market size,
- regional diversity in exports is influenced by accessibility to R&D, educated labour and producer services
- regional start up rates are dependent on accessibility to market size (Gross Regional Product and wage sum) and R&D,
- location decisions made by firms are explained by accessibility to market size (wage sum, producer services and manufacturing).

The table that follows presents, in short, the empirical studies included in this chapter.

Table 1: Empirical studies using the accessibility approach

	Dependent variable	**Accessibility variables (independent)**	**Unit of analysis**
Knowledge production			
Andersson & Ejermo (2004)	Patents	Company and university R&D	Functional regions
Andersson & Ejermo (2005)	Patents per corporation	Company and university R&D	Functional regions
Ejermo & Gråsjö (2008)	Patents per cap , Quality adjusted patents per cap	Company and university R&D	Functional regions
Gråsjö (2009)	Patents	Company and university R&D	Municipalities
Gråsjö (2012)	Patents	R&D, High valued imports	Municipalities
Productivity and growth			
Karlsson & Pettersson (2005)	Gross Reg. Prod. per km^2	Population, High-educated labour	Municipalities
Anderson & Klaesson (2006)	Growth in population, employment, commuting	Market size (wage sum)	Municipalities
Andersson, Gråsjö & Karlsson (2007)	Growth in Value added per employee	Company and university R&D	Municipalities
Andersson & Karlsson (2007)	Growth in Value added per employee	Knowledge resources	Municipalities
Andersson, Gråsjö & Karlsson (2008)	Wage sum per employee	University educated labour	Municipalities
Karlsson, Andersson & Gråsjö (2008)	Growth in Value added per employee	Company and university R&D	Municipalities

Andersson & Noseleit (2009)	Employment growth	Firm start-ups	Functional regions
Klaesson & Larsson (2009)	Wage sum per employee, Productivity and Industrial Composition index	Market potential (Gross regional product)	Municipalities
Ejermo & Gråsjö (2011)	Change in Gross regional product and wage sum	Patents , Quality adjusted patents	Functional regions
Company and University R&D			
Andersson, Gråsjö & Karlsson (2009)	Company R&D	University R&D, High education	Municipalities
Karlsson & Andersson (2006)	Company R&D University R&D	University R&D Company R&D	Municipalities
Exports			
Johansson & Karlsson (2007)	Exported goods, exporting firms, export destinations	Company and university R&D	Functional regions
Gråsjö (2008)	Total export value, high value exports	R&D, Human capital	Municipalities
Bjerke & Karlsson (2009)	Export value	Producer services	Functional regions
New firm formation			
Andersson & Hellerstedt (2009)	KIBS start-ups	Market potential (Wage sum)	Municipalities
Karlsson & Backman (2011)	Start-ups	Human capital	Municipalities
Grek, Karlsson & Klaesson (2011)	Entry and exit of firms	Gross Regional product	Municipalities
Andersson & Koster (2011)	Start-ups	Gross Regional Product	Municipalities
Karlsson and Nyström (2011)	Start-ups	Company and university R&D	Municipalities
Interaction and diversity			
Andersson & Klaesson (2009)	Entropy of establishments	Population	Municipalities
Location dynamics of firms			
Andersson (2006)	Employment manufacturing and producer services	Employment producer service Employment manufacturing	Functional regions
Johansson & Klaesson (2011)	Change in number of jobs	Market demand (Wage sum)	Functional regions
Labour mobility			
Andersson & Thulin (2011)	Labour mobility	Employment	Functional regions

4. Conclusions

The purpose of this paper was to show that the accessibility approach is a very useful analytical and empirical tool in spatial economics. We have illustrated how accessibility measures can be used in a spatial context to explain numerous economic phenomena, such as patent output, regional economic growth, new firm formation, the diversity of exports, etc.

The paper promotes the use of the accessibility concept for several reasons:

1. It is related to spatial interaction theory and can be motivated theoretically by adhering to the preference structure in random choice theory.[10]
2. It incorporates "global" spillovers and does not only account for the impact from neighbours or locations within a certain distance band.

[10] Fingleton (2003) remarks that the spatial weight matrix applied in many empirical studies is not underwritten by a strong theory and that the assumptions behind the chosen weight matrix are often not tested.

3. The separation into local, intra-regional and interregional accessibilities captures potential productive dependencies between locations and makes the inferential aspects more clear.
4. Distance is often measured by the physical distance, but a more appropriate and realistic measure in economic modelling is the time it takes to travel between different locations. The accessibility measure in this paper is constructed with the use of commuting time distance.
5. Econometric problems with biased parameter estimates are reduced even if the underlying spatial structure is spatially lagged dependent variables. In addition, the parameter estimates are much more efficient when the accessibility variables are included in the model.
6. The accessibility approach is of great interest for policy makers, since it makes it clear that an improved accessibility can be achieved in two ways. Either policy makers can improve the transport infrastructure and public transport to reduce travel times or they can increase the potentials in different municipalities. However, the accessibility approach also makes it obvious that it is of great importance which transports links that are improved, and where the increased potentials are located.

Being an underused analytical and empirical tool in spatial economics, we welcome more research that uses the accessibility approach in the future.

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