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R&D Accessibility and Regional Export Diversity

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Abstract

This paper examines the influence of accessibility to R&D on the regional diversity in Swedish export. A theoretical model with fixed R&D cost predicts that spatial knowledge spillovers generates external economies of scale in R&D activities and these external effects increase the innovative capacity in regions that have high accessibility to R&D. The model implies 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 hypothesis that regional accessibility to R&D facilities in the private business sector, on the one hand, and university research departments on the other hand, increases the export diversity in regions is tested in cross-regional regression models. Since knowledge cannot be regarded as a spatially trapped resource the empirical analysis includes two measures of R&D accessibility; intra-regional and inter-regional. The empirical results indicate 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.

Keywords: Export diversity, knowledge, accessibility
JEL classification: R11, R12, F12

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1. Introduction

It is today well established that R&D and innovation are of substantial importance for export performance at both the national (Fagerberg, 1988; Greenhalgh, 1990) and the firm level (Hirsch & Bijaoui, 1985; Ito & Pucik, 1993; Kumar & Siddharthan, 1994; Wakelin, 1998; Bernard & Jensen, 1999; Sterlacchini, 1999 & 2001; Bleaney & Wakelin, 2002; Barrios, Görg & Strobl, 2003). However, R&D activities are, in general, strongly concentrated to large functional urban regions and a large number of empirical studies in the last 15 years indicate that knowledge flows are bounded in geographical space. It is obvious that these two factors may play a fundamental role in shaping regional patterns of specialisation and comparative advantages (Grossman & Helpman, 1991). Actually, investments in R&D and exports may interact and thus create a benign circle for regions hosting significant R&D activities.[1] Nevertheless, most empirical studies of the role of R&D in determining patterns of trade specialisation have been conducted at the level of nations (Soete, 1981; Dosi, Pavitt & Soete, 1990; van Hulst, Mulder & Soete, 1991; Amendola, Dosi & Papagni, 1993; Magnier & Toujas-Bernate, 1994; Fagerberg, 1995; Amable & Verspagen, 1995; Amendola, Guerrieri & Padoan, 1998; Braunerhjelm & Thulin, 2004). These studies analyse the role played by technological variables in determining the dynamics of competitive advantages of advanced countries. They indicate the existence of a significant link between the R&D performance and the international trade performance of industrialised countries, i.e. that technology and firms' innovative activities can explain an important part of the variance in countries' export performance. In particular, they show that the dynamics of technological variables (world patent shares, relative R&D expenses, fixed investment, etc.) and the quality and novelty of products and production processes significantly affect the dynamics of world market shares in the advanced countries. There are few empirical studies of the possible links between the R&D specialisation of regions and their patterns of trade and comparative advantages (Sjöholm, 1996; Breschi & Palma, 1999), but they indicate a robust relationship between the innovative capabilities of regions and their trade performance.

The limited number of empirical studies of the possible links between the R&D specialisation of regions and their patterns of trade and comparative advantages is per se a motivation for conducting more empirical research. There are, however, also methodological reasons for doing more empirical studies. The new theory of specialisation and trade that has emerged within the so-called "New Economic Geography"-framework emphasises the role of the functional region rather than the nation (Johansson & Karlsson, 2001). The pertinent models are based on the assumption that the economy of a functional region primarily develops through self-organised interaction processes based upon decisions by households, companies and regional policy makers but which also includes interaction with economic actors in other self-organising functional regions. Earlier studies have normally been based upon a division in administrative regions, which do not need to be functional regions. Functional regions consists of nodes, such as municipalities, connected by economic networks and networks of infrastructure, and the borders of the

[1] The analysis of the determinants of the R&D specialisation of countries and regions and the role of export specialisation in that connection is not yet well developed (Malerba & Montobbio, 2000).

region are determined by where in geography the main direction of interaction is directed towards another region (Johansson, 1992). Following the recommendations in Andersson & Karlsson (2001), this paper defines regions as functional regions. Furthermore, earlier studies have used very crude measures to represent the role of proximity for knowledge exchange and thus for knowledge diffusion between economic actors. This paper uses an accessibility approach in analysing the impacts of R&D on export performance.

The purpose of this paper is to analyse the role of R&D accessibility for the export performance of regions in Sweden. In contrast to previous studies on regional export performance this empirical analysis emphasizes the role of R&D for regional export diversity. The particular issue of concern is whether the export of regions with larger accessibility to university R&D, on the one hand, and company R&D on the other hand, is more diversified than the export from regions with low accessibility to university and company R&D. Thus, the objective of this empirical study is not to analyze export performance in terms of total export value or volume but to investigate the export performance of regions in terms of number of exporting firms and number of export products. The reason to this approach is the recognition that a significant part of R&D efforts in Sweden is focused on product innovation (Nyström, 2006) and in accordance with the theory of product life cycles (Vernon, 1966), innovative products are initially sold in smaller flows than are standardized products. Hence, the short-run effects on R&D activities on regional export performance are likely to be captured by an expanding export base, rather than by expanding export volumes.

Furthermore, this paper examines a geographical dimension of regional export diversity in terms of the number of destinations that the export from a region reaches. Since the size of the regional market is always limited, firms have a natural incentive to export their product since the returns from R&D are higher when the innovations generated by R&D can be exploited in large foreign markets. Geographical export expansion is likely to be a result not only of successful product innovations but also by process innovations, which typically addresses the production of more standardized goods. Hence successful innovation will result in improved competitiveness either in terms of product characteristics (product innovation) or in terms of product price (process innovation). Assuming that R&D investments improves the competitiveness of export products there is an expected positive relationship between regional R&D activities and the geographical distribution of a region's export products in the global market.

In order to investigate the importance of R&D for regional export diversity three different indicators of diversity (number of exporting firms, number of export products and number of export destinations) is tested in a cross-regional regression analysis based on export data at the municipality (local government) level in Sweden in the year 2002. The motive to conduct the empirical analysis on the level of municipalities, which is an administrative geographical region rather functional region, is that the municipality level gives a larger number of observations. Nevertheless, this study emphasizes the role of the functional region in the measurement of R&D activities. Regional R&D efforts are measured as the accessibility to R&D workers in private business research labs and in academic research departments. Since labour and, in particularly, knowledge, is not fixed to a specific location the accessibility to R&D is measured at the level of labour market regions (intra-regional accessibility). Furthermore, the influence of the inter-regional knowledge spillovers is taken into account through measurements of accessibility to R&D in surrounding functional regions.

A theoretical conjecture that knowledge flows are bounded in space has been confirmed in a number of empirical studies. Already Jaffe, Trajtenberg & Henderson (1993) did show in an analysis of data on patent citations that knowledge flows are strongly geographically localised. Their findings suggest that the benefits of knowledge are higher in the region or country where it is generated than it is in other regions or countries. That the extent of knowledge flows is affected by geographical distance was shown even earlier by Jaffe (1989) in an analysis of the relationship between university R&D and patenting activity. Firms are overall more likely to benefit more from R&D conducted in universities located in their home states than from other universities. In the two empirical studies mentioned here, the spatial scale of analysis is the state level in the US, i.e. they are based on administrative regions that are substantially larger than a functional urban region in Sweden. There are however also studies of knowledge flows at the level of metropolitan regions. Anselin, Varga & Acs (1997) analysed local knowledge flows between university R&D and innovative activities by small high technology firms using innovation counts for 125 metropolitan regions in the US. They found that knowledge flows from university R&D have a positive and significant impact on regional rates of innovation. They also found that the impacts extend over a range of 120 kilometres from the innovating region implying that spatial contiguity is important for knowledge flows and that knowledge flows extend beyond the borders of functional regions

However, no functional region can develop in splendid isolation. Functional regions can increase its knowledge production by improving its links with other regions, in particular with large functional urban regions with an extensive knowledge production, thereby improving its inter-regional and international knowledge networks. Indeed, R&D has become much more global during the past two decades as multi-national companies invest resources to exploit sources of knowledge at the locations of important customers and competitors (Howells & Wood, 1993; Florida, 1997; Gassman & von Zedtwitz, 1998 & 1999; Blanc & Serra, 1999; von Zedtwitz & Gassman, 2002). Large functional regions often have special advantages in this respect since they normally are well connected in the international air travel networks, are important import nodes for new products, have large research universities, etc. The costs for accessing knowledge from other regions are normally lower in large functional urban regions than in small functional regions. Furthermore, large urban regions have a larger number of knowledge handlers that can operate in the different inter-regional and international knowledge networks and evaluate and apply the knowledge emanating from interaction with external economic agents.

The outline of the paper is as follows: In the next section a spatial model of production with fixed R&D costs is outlined. Section three addresses two important empirical issues, namely the definition of functional regions and the measurement of regional accessibility to R&D. In section four the empirical results are presented and discussed and the outcomes and implications of this study is finally summarized in section five.

2 Theoretical Framework

The traditional theory of international trade focuses on the supply side, i.e. on durable capacities in terms of availability of production factors and especially regionally trapped factors. Models in this tradition adhere to the resource-based theory of specialisation. Up till the early 1980's, regional comparative advantages have, with few exceptions, been derived from resource-based models. With durable capacities as the only explanatory factor of trade patterns it is very difficult to understand why almost identical products are produced in different regions and then traded between the same regions. The limitations of the traditional theory based upon resource endowments is that it cannot explain regional specialisation in an acceptable way, i.e. differences in resources (factor intensities) can explain only certain parts of the trade flows and the pertinent location of production.

In recent decades, a partly revolutionary change has occurred within international economics focusing on the importance of scale and market effects. This "new" approach claims that economic specialisation to a large extent is based on increasing returns (Dixit & Norman, 1980; Lancaster, 1980; Krugman, 1979, 1980 & 1981; Ethier, 1982; Helpman, 1984). According to the new theory of trade with its scale-based models, imperfect competition and increasing returns are pervasive features of contemporary industrialised economies. With increasing returns as a basic explanation, trade develops because the existence of advantages of specialisation also among regions, which are very similar to each other in terms of resource endowments. If specialisation and trade are driven by economies of scale rather than by comparative advantage, the gains from trade arise because production costs fall as the scale of output increases. In the following subsection a spatial model with increasing returns to scale, based on the classical model by Krugman (1980) is outlined.

2.1 A Spatial model with fixed R&D costs

In its simplest form increasing returns can be the result of the existence of some fixed costs at the level of the individual firms. The type of fixed costs that is considered in this model is the cost of conducting R&D. Assume that the production of manufacturing goods exhibits increasing returns according to the following formulation:

$$L_M = L_{R\&D} + aQ_M \qquad (2.1)$$

where L_M represents the total amount of labour employed by each firm, $L_{R\&D}$ represents the fixed amount of R&D personnel employed by each firm, a is a constant reflecting the per unit labour input in manufacturing and Q_M is the output of each manufacturing firm. Assuming now that consumers have preference for product variety, the existence of increasing returns imply that each manufacturing firm will produce a single unique product. In such a monopolistically competitive milieu the number of manufacturing firms will be equal to the number of manufacturing products. Each monopolistic producer perceives the elasticity of demand for its own product as equal to σ. Assuming that labour is the only factor of production in manufacturing, the output price mark-up on the producers marginal costs can be expressed as:

$$P_i(1-1/\sigma)=aw \qquad (\sigma>1) \tag{2.2}$$

where P_i is the price of product variety i and w is the wage rate. For simplicity we assume that the wage rate is the same for R&D and manufacturing labour. Equation (2.2) can be transformed into:

$$P_i = \left(\frac{\sigma}{\sigma-1}\right)aw \tag{2.3}$$

When price equals marginal costs there are zero profits. Under these circumstances the ratio $\sigma/(\sigma-1)$ can be interpreted as an index of economies of scale. However, it is also a parameter of consumer preference for variety. The assumption that freedom of entry within the monopolistically competitive milieu leads to zero profits, implies that revenue must equal costs:

$$P_i^*Q_M = w_M\left(L_{R\&D}+aQ_M\right) \tag{2.4}$$

where P_i^* is the equilibrium price. Combining Equations (2.3) and (2.4) generates

$$Q_M^* = \frac{L_{R\&D}(\sigma-1)}{a} \tag{2.5}$$

where Q_M^* is the profit-maximising output level of a manufacturing firm. The equilibrium labour demand for a firm, L_M^*, is given by

$$L_M^* = L_{R\&D} + a\frac{L_{R\&D}(\sigma-1)}{a} = L_{R\&D}\sigma \tag{2.6}$$

Given that there are $\overline{L}$ manufacturing workers in a region, the number of goods produced in its manufacturing sector, *n,* is determined by:

$$n=\frac{\overline{L}}{L_M^*}=\frac{\overline{L}}{L_{R\&D}+a\,L_{R\&D}(\sigma-1)/a}=\frac{\overline{L}}{L_{R\&D}\sigma} \tag{2.7}$$

i.e. the volume of R&D labour needed to create a good determines the number of goods produced in a region and thus the number of potential export goods[2]. Equation (2.7) also implies that the larger is the region, i.e. the larger $\overline{L}$, ceteris paribus, the larger the num-

[2] If we allow for multi-product firms, the fixed R&D costs might be distributed over several products and further increase the number of products as a result of economies of scope.

ber of goods produced and naturally the number of potential export goods. Moreover, equation 2.4 and 2.5 implies that there are economies of scale in R&D activities, but the scale effect, $\sigma/(\sigma-1)$, diminishes the larger is σ. This is because the larger is σ, the larger is the elasticity of substitution between any two varieties of manufactured goods, implying the price elasticity of demand is high. Hence, the number of goods produced in a region is decreasing in σ and negatively related to the number of workers employed in R&D activities. Thus, equation 2.7 states that, the larger is the R&D input in production the less diversified will a region be.

However, the result in (2.7) may be extended to include the influence of external knowledge flows, in the literature often named "knowledge spillovers". This is illustrated in equation (2.8).

$$n = \frac{\overline{L}}{\left(L_{R\&D}\right)^{(1/\varphi)}\sigma} \qquad \varphi \geq 1 \tag{2.9}$$

When $\varphi = 1$ there is no external knowledge flows that influence the R&D activities of firms but when $\varphi > 1$ there are knowledge flows from other firms and university research that reduces the volume of own R&D necessary to produce a good. This implies that the efficiency of R&D workers increases due to knowledge spillovers, which indicates that there are external economies of scale in innovating activities. Numerous studies have addressed the importance of geographical proximity in knowledge diffusion. Consequently, these knowledge spillovers are likely to be a result of agglomeration of R&D activities. The model outlined in this section implies that the richer the knowledge milieu of a region the more efficient is the innovative activities and the more goods will be generated and the more potential export goods the region will host. The geographical aspects of the knowledge flows that produce this theoretical outcome are thoroughly discussed in the next subsection.

2.2 Spatial Knowledge Flows

As recognized by Cheshire & Malecki, 2004, a firm's own R&D alone is no longer sufficient for technological competitiveness. Internal R&D must be complemented by external sources of knowledge, which in turn must be integrated into the firm's competencies and structures (Malecki, 1997; Amin & Cohendet, 1999; Kuemmerle, 1999). Another well-known result from the literature is that knowledge tends to flow between economic agents. Thus, the cost of R&D, which is assumed to be fixed, is dependent upon the richness of the knowledge flows in each region. The richer are knowledge flows in a functional urban region, the lower the fixed R&D costs and the larger the number of manufactured products produced and the larger the number of manufacturing firms and the larger the number of potential export goods, *ceteris paribus*. In the sequel, we will extend the discussion of knowledge flows in functional urban regions and their influence on regional export activities, but first we must say a few words about the special characteristics of knowledge.

Knowledge is a very special kind of economic good. A particular feature of knowledge is that it is non-rivalrous, i.e. its use by one economic agent in no way limits its use by other economic agents. In this respect, knowledge is a pure public good. However, for certain types of knowledge, it is possible to exclude other economic agents from using it commercially by means of patents, trade secrets, etc. Thus, not all knowledge is a pure public good in the sense that every economic agent freely can use it for what ever purpose he wants. Nevertheless, even if excludability prevails as regards commercial use, the actual knowledge can still be used in the generation of new knowledge. Actually, patent applications are often studied intensively by competitors to reveal the knowledge protected by the patent to be used as an input in the competitors' own R&D. Reversed engineering is used for the same purpose.

However, the fact that knowledge is non-rivalrous and, in principle, also non-excludable when it comes to be used in further R&D does not imply that knowledge is freely accessible without costs at any point in geographical space. Firstly, for new pieces of knowledge to be useful, the user must possess the relevant training and/or experience to fully grasp the implications of the new knowledge, i.e. he or she must be what we can term a knowledge handler. Furthermore, much knowledge is tacit or sticky in the sense that it is not codified. This is certainly true for newly generated knowledge by means of R&D. Such tacit knowledge is mainly exchanged through informal channels for interpersonal contacts, such as face-to-face communications, meetings, seminars, supervision, on-the-job training and other similar channels, whose effectiveness decreases with the time distance between the knowledge handlers involved (Pred, 1966; Feldman, 1994). Thus, the transmission and absorption of technological and scientific knowledge is facilitated by geographical proximity. Since all knowledge handlers have their specific location in geographical space, knowledge exchange will take place in different spatial "knowledge" networks. These networks may be but need not be related to business transactions. Geographically, they may be local, intra-regional, inter-regional or international and by having one or several nodes in common these networks are interlinked in multitude ways.

Networking is a costly and time consuming activity. Since networking on distant links is more costly than on local links, interaction will be much more frequent on local and intra-regional links, i.e. in local and intra-regional networks. This effect might be quite pronounced, since spatial interaction costs may increase in a non-linear manner at certain distances (cf. Johansson & Karlsson, 2001). The overall effect is that the majority of knowledge flows tend to be bounded in geographical space. Moreover, the more tacit, sticky and complex is the knowledge bases, the more probable it is that geographical proximity will play a significant role in facilitating the transmission of such knowledge (Breschi & Palma, 1999). Hence, the spatial patterns of knowledge flows may vary across industrial sectors due to different knowledge bases. The geographical limitations of knowledge flows imply that there is a high probability that different regions will develop their own specialised knowledge base in a path-dependent manner. It also implies that regions that deliberately increase their investments in R&D and/or develop arenas for interaction between knowledge handlers and improve intra-regional transport infrastructure may develop an increased comparative knowledge advantage vis-à-vis other regions over time.

Summarising the arguments that far, we may hypothesise that the number of export products in a region will be a positive function both of its intra-regional R&D efforts and its exposure to knowledge generated in other regions. However, it is not only the number of export products that are influenced by the R&D efforts. The basic theory assumes that each firm is producing a single product and in equilibrium all firms have the same cost structure, the same size and, consequently, all products have the same price. Putting a bit more of realism into the theoretical thinking it is likely that there are significant economies of scope in R&D activities. In absence of intra-regional and inter-regional knowledge spillovers R&D investments are likely to be most prevalent in large firms and resulting in extended product lines in a few large firms. However, when there are external economies of scale in knowledge production the number of exporting firms is expected to increase with the innovative capacity of the region. Furthermore, the number of destinations for a region's export is likely to increase with R&D investments. This is because successful innovation will result in improved competitiveness either in terms of product characteristics (product innovation) or in terms of product price (process innovation). In the case of product R&D the innovating firm has an initial monopolistic market position, but the monopoly power are likely to cease as imitating firms (domestic or foreign) adopts the new technologies and are able to copy new products (Klette and Kortum, 2004). For the innovating firm the penetration of a large number of foreign markets is of essential importance for having positive returns to investments in R&D since monopoly profits fades over time. In the case of process innovation on the other hand, the geographical expansion of export is an effect of successful price competition in products that are already well established among consumers. If firms that are conducting process innovations becomes more efficient and produces at lower price than their competitors they are able to increase their world market share at the expense of other firms. Hence, the more successful the innovation efforts are the larger geographical distribution will a specific product achieve, independently of the type of innovative effort.

The predictions of the theoretical model presented in this section is that regional R&D activities play a fundamental role in increasing the regional diversity of export i.e. the regional export base. Yet, before plunging into empirical testing, a thorough discussion of the definition of functional regions and how their geographical interactions may be measurable is appropriate.

3 Empirical Methodology

Before testing our hypotheses empirically we have to solve the problem of how to measure R&D and how to deal with the problems of spatial auto-correlation, i.e. the fact R&D conducted in one region may spill over to other regions. We suggest that R&D can be measured by man-years of working time devoted to R&D and that the number of man-years should be discounted by travel times to acknowledge the frictions in the knowledge networks.

3.1 The Functional Urban Region

In the measurement of geographical accessibility the idea of the functional urban region (FUR) is a prime concept. A FUR is distinguished by its concentration of activities and of its infrastructure which facilitates a particularly high interaction frequency within its borders. In particular, a FUR is characterised by being an integrated regional labour market, i.e. a commuting region. Commuting and all forms of face-to-face interaction give rise to spatial interaction costs. The size and the spatial pattern of these interaction costs determine the geographical boundary of each FUR. A basic component of these spatial interaction costs is transport costs, since much interaction involves some kind of exchange, for example the exchange of goods, services, information, knowledge, etc. In addition, all such exchanges generate some sort of transaction cost, which may vary with geographical distance and with the properties of each specific interaction link. Thus, the spatial interaction costs for a given exchange is the sum of the transport costs and the transaction costs that such an exchange generate.

For the analysis of regional export diversity this paper employs the following assumptions:

1. The borders of a FUR are identified by its overall pattern of spatial interaction costs. For certain activities, such as knowledge exchange, the spatial interaction costs are considerably higher outside than inside the borders of a FUR.
2. The internal market potential of a FUR is determined by the population size and its associated purchasing power.
3. Each FUR is connected to external markets via networks for trade and other economic interaction, which determine its external market potential. The interaction intensity varies across such networks, which makes it possible for each FUR to identify a hierarchy of sequentially widening transaction of affinity areas, such that spatial interaction costs rise in a step-wise sequence. Large FURs are generally connected by many more networks than small FURs.
4. The total market potential of a FUR is composed of its internal and its external market potential.
5. Location of economic activities in a FUR is a process which is influenced by two basic conditions: (i) durable regional capacities, (ii) technology, scale and market effects.

Turning the interest to the issue of geographical proximity there are, from the perspective of a functional urban region basically two types of travel times: travel within the functional urban region and travel times to all other regions. This implies that for the two types of R&D: company R&D and university R&D two relevant measures of geographical proximity are computable – one intra-regional and one inter-regional. To do this we use an accessibility approach that is presented in detail below.

3.2 Accessibility Defined

Consider a set of *n* of regions. The accessibility of region *i* (within the *n* regions) to itself and to the n-1 surrounding regions can be defined as follows,

$$A_i^D = D_i f(c_{ii}) + D_1 f(c_{i1}) + D_2 f(c_{i2}) + \dots + D_n f(c_{in}) \qquad (3.1)$$

where $A^D{}_i$ is the total accessibility of region i. D_i is a measure of opportunities such as suppliers, customers, producer services, educated labour, universities and R&D institutes, etc, in each region (Klaesson, 2001). A region's accessibility is defined as the sum of its internal accessibility to a given opportunity *D* and its accessibility to the same opportunity in all the other regions in the set $\{1,\dots,n\}$. *f(c)* is a distance decay function that determines how the accessibility value is related to the cost of reaching the opportunity, (Andersson & Johansson, 1995). Different researchers have used different specifications of this relationship but one of the most common approximations is made by means of an exponential function, (Johansson & Klaesson, 2001). When applying an exponential function, the distance decay function takes the following form:

$$f(c_{ij}) = \exp\{-\lambda t_{ij}\} \qquad (3.2)$$

where t_{ij} is the time distance between region *i* and *j* and λ is a time-sensitivity parameter, which determines how the accessibility responds to changes in *t*. Combining Equations (3.1) and (3.2), the accessibility of region *i* to opportunity *D* is defined in as:

$$A_i^D = \sum_{j=1}^{n} D_j \exp\{-\lambda t_{ij}\} \qquad (3.3)$$

An accessibility of the type that is discussed here should satisfy certain criteria of consistency and meaningfulness. It should be emphasized that the expression in (3.3) satisfies such warranted criteria (Weibull, 1976). Moreover, following the recommendations in Andersson & Karlsson (2001), local labour market regions can be used as proxies for functional regions. Given that, labour market regions have the properties that distinguishes functional urban regions, it is possible and relevant to divide a region's total accessibility to some opportunity *D* ($A^D{}_R$) into three parts:

$$A_R^D = A_{RL}^D + A_{RI}^D + A_{RE}^D \qquad (3.4)$$

,where $A^D{}_{RL}$, $A^D{}_{RI}$ and $A^D{}_{RE}$ express local accessibility, intraregional accessibility and interregional accessibility respectively. Table 3.1 below describes the different categories of accessibility.

Table 3.1 Different categories of accessibility

Accessibility	Approximate time distance	Range
Local	5-15 minutes	several unplanned contacts per day
Intra-regional	15-50 minutes	contacts and travels made on regular basis (commuting), once per day
Inter-regional	>50 minutes	planned contacts, low frequency

As seen in Table 3.1, local accessibility is relevant to unplanned contacts. The time distance is sufficiently low to make it possible for persons to carry out several contacts within a day. Intraregional accessibility, on the other hand, is relevant to contacts and travels made on a regular basis, such as commuting. The time distance is too large for several unplanned contacts during one day. For interregional accessibility, the time distance is too large for commuting. The contacts made in this range are therefore likely to constitute planned activities, such as business meetings, fairs, conferences etc.

Given the approximate time distances set out in Table 3.1, it is worthwhile noting that the relevant mode of transport may differ between the three accessibilities. Referring to local accessibility, car and local busses are likely to be the relevant modes of transport. For intraregional accessibility, regional trains should be added. In the time distance corresponding to interregional accessibility, it is likely that busses and cars are to a high degree substituted in favour of high-speed trains and air travels. These observations have implications with regard to the measurement of time distances and are also important from a policy perspective.

Furthermore, that the time sensitivity parameter λ is different for local, intra-regional and inter-regional interaction (Johansson, Klaesson and Olsson, 2002). Inside a municipality parameter λ^1 applies, inside the pertinent region parameter λ^2 applies and for contacts outside the region parameter λ^3 applies. These differ in size in the following way: $\lambda^2 > \lambda^3 > \lambda^1$, which means that the time friction is greater for time intervals of the size 15-50 minutes, smaller for intervals longer than 50 minutes and smallest for very short time distances.

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

$$A_{sM}^{D} = \exp\{\lambda^1 t_{ss}\} D_s \tag{3.5a}$$

In municipality s the economic actors have accessibility to opportunity D_r in all other municipalities *r* that belong to region *S*. By letting t_{sr} denote the time distance between municipality *s* and *r* the intra-regional accessibility of municipality s can be expressed as

$$A_{sS}^{D} = \sum_{r \in S,\ r \neq s} \exp\{-\lambda^2 t_{sr}\} D_r \qquad (3.5b)$$

Economic actors such as firms and households in municipality *s* also have accessibility to opportunity D_k in the *k* municipalities outside region S. This external accessibility is specified in formula (3.5c).

$$A_{sE}^{D} = \sum_{k \notin S} \exp\{-\lambda^3 t_{sk}\} D_k \qquad (3.5c)$$

With these notations the three categories of accessibility can formally be expressed in the following way

(i)	Local accessibility	$= A_{sL}^{D} = \sum_{s \in R} A_{sM}^{D}$	(3.5d)
(ii)	Intra-regional accessibility	$= A_{sR}^{D} = \sum_{s \in R} A_{sS}^{D}$	(3.5e)
(iii)	Inter-regional accessibility	$= A_{sRE}^{D} = \sum_{s \in R} A_{sE}^{D}$	(3.5f)

By using (3.5d) – (3.5e) it is possible to calculate the aggregated intra-regional accessibility of municipality s in region R as follows:

$$A_{sIR}^{D} = A_{sL}^{D} + A_{sR}^{D} \qquad (3.5g)$$

Thus, we have two measures describing the accessibility conditions for municipality s regarding the opportunity *D*, namely its aggregated intra-regional accessibility, A_{sIR}^{D}, and its inter-regional accessibility, A_{sRE}^{D}.

3.3 Data and regression model

At the purpose of analysing the relationships between regional export diversity and regional accessibility to R&D this empirical study is based on cross-regional data of Swedish export firms in the year 2002. In this data the location of the exporting firm is defined at the municipality level, which gives 289 possible locations in Sweden. The data classifies the export of all products according to the 8-digit level of the combined nomenclature, which has been used to define the number of export products at the municipality level. The data set also includes the destination of each firm's export of a particular good, which has been used to determine the number of destinations for the export from each municipality. Since each municipality forms part of a larger labour market region where regular commuting is extensive, the local accessibility to R&D worker alone is of minor importance. Instead, this empirical analysis focus on the intra-regional accessibility to

R&D labour (which is the sum of the local and regional accessibility measures) and the inter-regional accessibility to R&D labour. The measures of the intra- and inter-regional accessibility to university and company R&D labours is calculated as an average for the years 1993 to 1999. Hence, it is assumed that the effects of R&D on export diversity persist over time. Descriptive statistics of the dependent and independent variables are reported in appendix.

The impact of intra- and inter-regional accessibility to R&D on the regional export diversity is estimated by the following cross-regional model:

$$n_s = \alpha + \beta_1 A^D_{sIR} + \beta_2 A^D_{sRE} + \beta_3 S_s + \varepsilon_s \tag{4.1}$$

where the dependent variable, n, denotes number of export goods in municipality s, α is the intercept term, A^D_{sIR} and A^D_{sRE} is the variables reflecting intra- and inter-regional accessibility to R&D respectively (as defined in section 3). S is the size of municipality s, measured by its population used as a control variable for the different sizes of the municipalities and ε is a stochastic error term. However, the Breusch-Pagan test for homoscedasticity indicates that the OLS estimates are heteroscedastic, for what reason the regressions are estimated by FGLS, using White's robust covariance matrix. Furthermore, a particular feature of the location of R&D activities in Sweden is their concentration to large urban regions. This results in a high multi-collinearity between the two types of R&D labour considered in this paper (i.e. university and company R&D workers respectively). At the purpose of facilitate interpretation of estimated coefficients, the regression model in equation 4.1 is estimated in two different specifications, one including accessibility to company R&D workers and the other including university R&D workers.

4. Empirical Results

The hypothesis tested in this empirical analysis is that regional export diversity is positively affected by the accessibility to R&D facilities. Three indicators of export diversity is used; 1) the number of export goods 2) the number of exporting firms and 3) the number of export destinations. As discussed in the theoretical section, the basic spatial model of production with increasing returns to scale implies that the larger is the fixed R&D costs, the smaller is the number of goods produced (exported) in a region. Hence, if R&D-intensive production is located in regions with high accessibility to R&D, the predictions of the basic model is that there should be a negative relationship between intra-regional accessibility and the number of exporting goods/firms exported. However, introducing the possibility of knowledge spillovers as an externality giving rise to external scale economies into the basic model alters its predictions. If the efficiency of R&D activities is higher in regions with high intra- and inter-regional accessibility to company and university R&D facilities one would expect such regions to generate a larger range of export goods, hence being more diversified than regions with low accessibility to R&D.

In this case there should be a positive relationship between R&D accessibility and number of exporting firms as well as the number of exported goods.

The two specifications (the first including company R&D and the second including university R&D) of the regression model presented in section 3.3 are estimated in a cross-regional setting both on the total export of all types of commodities and in commodity-group regressions on 10 sub-groups of commodities. Furthermore, the regression model is applied on the three different measures of export diversity (number of export products, number of exporting firms and number of export destinations).

The first estimations consider the impact of R&D accessibilities on the number of exported goods in each municipality. The results of these regressions are presented in table 4.1a (company R&D) and table 4.1b (university R&D). The estimated results for the aggregate export of all commodities (the second row in table 4.1a) reveals that the number of products that is exported from a municipality is positively affected by the municipality's intra-regional and inter-regional accessibility to R&D workers employed in private company labs. Naturally, the size of the municipality has also a strong impact on the number of exported products, which supports the basic theoretical assumption of increasing returns to scale in the production of differentiated manufactured goods. Small municipalities specialize in the production of a smaller range of products whereas large municipalities achieve a more diversified export since more firms are able to produce at the minimum efficient scale. The regressions estimated on specific commodity groups reveals that the size variable is significant in all cases but its impact seems to be smaller for goods that are closely related to a specific natural resource such as mineral and wood products.

Moreover, the accessibility to R&D seems to be more important in diversifying the export base in commodity groups that are R&D-intensive. Telecom and electronic products have the strongest estimated coefficient for both intra-regional and inter-regional accessibility to company R&D labour, followed by chemical products and industrial machinery. Furthermore, there seems to be a consistent pattern of R&D dependence for the export diversity; commodity groups which export base increases with the intra-regional R&D accessibility also experience a positive impact of inter-regional accessibility to R&D labour. For the production of motor vehicles and other transport equipment the inter-regional accessibility to R&D have a significant positive impact on the number of exported goods in a particular location whereas the intra-regional R&D accessibility is far from significant. In low-tech industries such as food, textiles, wood and paper and metal products the accessibility to R&D have no significant effect on the number of export products produced in a specific location.

Table 4.1a Effects of accessibility to company R&D on the number of export products

Commodity Group	Intra-regional access to company R&D	Inter-regional access to company R&D	Size	Constant	R^2
All commodities	1.6067* (2.811)	3.5772* (2.320)	0.0071* (5.513)	130.060* (4.021)	0.75
1. Agricultural and food products	0.0965 (1.507)	0.1352 (0.791)	0.0009* (10.726)	-5.498* (-1.915)	0.73
2. Mineral based products	0.0552* (2.310)	0.115* (1.963)	0.0004* (6.957)	3.976* (2.758)	0.77
3. Chemical products	0.2855* (3.001)	0.5605* (2.710)	0.0010* (4.644)	10.531 (2.175)	0.72
4. Products of wood and paper	0.0378 (0.743)	0.1077 (1.370)	0.0004* (5.110)	17.653* (8.000)	0.60
5. Products of textile, leather and fur	0.2155 (1.219)	0.6719 (1.165)	0.0009* (4.646)	11.206 (1.424)	0.46
6. Metal products	0.1210 (1.568)	0.3146 (1.741)	0.0009* (4.417)	22.756* (4.519)	0.64
7. Industrial machinery	0.1965* (2.574)	0.5230* (2.420)	0.0009* (4.522)	34.947* (6.554)	0.66
8. Motor vehicles and transport equipment	0.0076 (0.439)	0.1006* (2.570)	0.0003* (5.939)	9.029 (7.298)	0.70
9. Telecom and electronics	0.5360* (4.684)	0.7492* (2.738)	0.0009* (3.780)	20.972* (3.279)	0.68
10. Furniture, arts and sport articles	0.0571 (1.454)	0.2271* (2.288)	0.0003* (5.513)	12.845* (4.021)	0.50

t-values in parenthesis. * denotes significance at 5%.

Turning the interest to university R&D activities, table 4.1b shows that the intra-regional accessibility to university R&D labour is significant only for the most R&D-intensive industries, i.e. chemical products and telecom and electronics. However, the inter-regional accessibility to university R&D have significant positive influences on the number of export products in all commodity groups but agricultural products and food, wood and paper, and textiles. One reason to the predominance of inter-regional knowledge flows over intra-regional flows in explaining variations in the export diversity between municipalities is that many Swedish municipalities have very similar intra-regional accessibility to university R&D, whereas the variable measuring inter-regional accessibility to university R&D contains larger variation.

In accordance with the theoretical model the empirical results indicate a positive impact of the intra-regional and inter-regional accessibility to R&D on the number export goods, particularly in the case of company R&D. An interesting feature is that there seem to be significant inter-regional knowledge spill over effects.

Table 4.1b. Effects of accessibility to university R&D on the number of export products

Commodity Group	Intra-regional access to university R&D	Inter-regional access to university R&D	Size	Constant	R^2
All commodities	0.1533 (1.441)	0.4975* (2.958)	0.0076* (5.767)	135.634* (4.296)	0.75
1. Agricultural and food products	-0.0006 (-0.005)	0.0238 (1.099)	0.0005* (2.445)	-5.584* (-2.162)	0.72
2. Mineral based products	0.0057 (1.256)	0.0174* (2.292)	0.0004* (7.211)	4.055* (2.871)	0.76
3. Chemical products	0.0322* (2.020)	0.0832* (3.087)	0.0011* (4.995)	10.915* (2.238)	0.72
4. Products of wood and paper	0.0030 (0.409)	0.0146 (1.552)	0.0004* (5.150)	17.852 * (7.923)	0.60
5. Products of textile, leather and fur	0.0123 (0.458)	0.0506 (1.049)	0.0011* (5.353)	16.033* (2.661)	0.44
6. Metal products	0.0076 (0.529)	0.0377* (2.070)	0.0009* (4.501)	23.792* (4.656)	0.63
7. Industrial machinery	0.0180 (1.184)	0.0803* (3.022)	0.0010* (4.542)	35.107* (6.504)	0.66
8. Motor vehicles and transport equipment	0.0006 (0.259)	0.0125* (2.501)	0.0003* (5.371)	9.286* (6.976)	0.70
9. Telecom and electronics	0.0686* (3.330)	0.1397* (3.235)	0.0010* (4.202)	19.112* (3.076)	0.69
10. Furniture, arts and sport articles	0.0056 (0.877)	0.0276* (2.584)	0.0003* (4.245)	13.50* (6.158)	0.50

t-values in parenthesis. * denotes significance at 5%.

Addressing the issue of export diversity in terms of the number of exporting firms, table 4.2a presents the result of the estimation of the impact of company R&D accessibility on the number of exporting firms. These estimates indicate a significant positive effect of the intra-regional accessibility to R&D on the number of exporting firms in a municipality. The estimated regression coefficients for the sub-groups of products signify that the importance of intra-regional accessibility is most important for R&D-intensive product groups (telecom and electronics, industrial machinery and chemicals) whereas the number of exporting firms in product groups consisting of agricultural and food products, metal products and motor vehicles and equipments do not capture any significant influences from intra-regional R&D efforts in the private business sector.

An interesting feature is that in the number of exporting firms in a municipality is not significantly affected by R&D activities performed in municipalities outside the own functional region. This outcome stands in sharp contrast to the estimates from the previous regressions, concerning the number of export products, where inter-regional knowledge spillovers appears to be an important factor in explaining the extension of municipalities' export bases in terms of number of exported products. Hence, variations in the number of exporting firms among municipalities is only be explained by variations in the accessibility to R&D within the own functional region whereas the accessibility to external R&D is also an important factor when explaining variations in the number of goods exported at the municipality level. These results indicate that a part of the R&D efforts made in private business labs result in extended product variety in other regions, which suggests that there are some economies of scope in R&D activities. Hence, it seems like knowledge generated by R&D activities in private companies are diffused by intra-firm and intra-industry linkages.

Table 4.2a The effects of accessibility to company R&D on the number of exporting firms.

Commodity Group	Intra-regional access to company R&D	Inter-regional access to company R&D	Size	Constant	R^2
All commodities	0.3342* (2.545)	-0.4894 (-1.124)	0.0047* (11.170)	-43.948* (-4.015)	0.93
1. Agricultural and food products	0.0204 (1.910)	-0.0055 (-0.150)	0.0003* (13.577)	-3.133* (-4.571)	0.89
2. Mineral based products	0.0398* (2.501)	-0.0245 (-0.475)	0.0005* (13.532)	-4.535* (-4.343)	0.91
3. Chemical products	0.1080* (2.948)	-0.0231 (-0.187)	0.0010* (4.611)	-10.234 (-4.767)	0.91
4. Products of wood and paper	0.1331* (2.190)	-0.1895 (-1.033)	0.0017* (7.960)	-19.999* (-3.864)	0.89
5. Products of textile, leather and fur	0.0601* (2.110)	0.0216 (0.130)	0.0008* (10.701)	-11.145* (-4.088)	0.86
6. Metal products	0.4042 (1.679)	-0.0238 (-0.248)	0.0010* (11.296)	-3.064 * (-1.614)	0.89
7. Industrial machinery and arms	0.1714* (3.000)	-0.1411 (-0.895)	0.0016* (14.132)	-12.659* (-4.159)	0.93
8. Motor vehicles and transport equipment	0.0058 (0.478)	-0.0157 (-0.408)	0.0005* (7.852)	1.172 (0.956)	0.89
9. Telecom and electronics	0.2594* (3.632)	-0.2078 (-1.164)	0.0017* (8.157)	-25.088* (-4.573)	0.91
10. Furniture, arts and sport articles	0.0509* (2.048)	-0.4998 (-0.510)	0.0008* (11.184)	-7.278 (-4.015)	0.89

t-values in parenthesis. * denotes significance at 5%.

In table 4.2b the regression results of the impact of university R&D on the number of exporting firms are presented. In these regressions none of the accessibility variables have any significant impact on the number of exporting firms in any product group. The high explanatory power of the model is to be derived only from the size of the municipality.

Table 4.2b The effects of accessibility to university R&D on the number of exporting firms.

Commodity Group	Intra-regional access to university R&D	Inter-regional access to university R&D	Size	Constant	R^2
All commodities	0.0090 (0.276)	-0.0103 (-0.353)	0.0049* (10.124)	-48.656* (4.252)	0.92
1. Agricultural and food products	0.0009 (0.337)	0.0013 (0.324)	0.0003* (14.167)	-3.281* (-5.347)	0.89
2. Mineral based products	0.0014 (0.337)	0.0029 (0.481)	0.0005* (13.723)	-4.972* (-5.287)	0.91
3. Chemical products	0.0081 (0.880)	0.0067 (0.559)	0.0019* (14.220)	-10.954* (-6.341)	0.90
4. Products of wood and paper	0.0035 (0.257)	-0.0014 (-0.112)	0.0017* (7.235)	-22.038* (-3.958)	0.89
5. Products of textile, leather and fur	-0.0013 (-0.155)	0.0067 (0.565)	0.0010* (10.237)	-11.301* (-5.124)	0.86
6. Metal products	-0.0008 (-0.117)	0.0003 (0.003)	0.0009* (13.349)	-3.271 (-2.145)	0.89
7. Industrial machinery and arms	0.0126 (0.883)	0.0043 (0.328)	0.0017* (13.624)	-14.585* (-5.115)	0.93
8. Motor vehicles and transport equipment	0.0003 (0.014)	-0.0006 (-0.121)	0.0005* (8.259)	1.032 (0.844)	0.89
9. Telecom and electronics	0.0217 (1.388)	0.0057 (0.410)	0.0019* (7.169)	-27.927* (-4.486)	0.90
10. Furniture, arts and sport articles	-0.0009 (-0.152)	0.0009 (0.125)	0.0009* (10.420)	-7.868* (-4.252)	0.89

t-values in parenthesis. * denotes significance at 5%.

The final measure of export diversity examined in this paper is the number of destinations for the exports from a municipality. The impact of intra-regional and inter-regional accessibility to company and university R&D on the geographical diffusion of regional export is presented in table 4.3a and 4.3b below. Starting with company R&D (table 4.3a) the regression estimates signify that the intra-regional accessibility to company R&D is important in explaining regional variations in the number of export destinations for the most R&D intensive product groups (telecom, chemicals and industrial machinery) but also for agricultural and food products as well as for textiles. Just as in the regressions of number of export products, there are significant inter-regional spillovers from R&D for the majority of product groups. Only products of wood, paper and textiles do not seem to be significantly affected by inter-regional accessibility to company R&D (yet these groups are significant at the 10 percent level). These results suggest that the number of export destinations for a municipality is increasing with the accessibility to knowledge, not primarily in the own functional region but with the accessibility to R&D conducted by firms in other region. Hence, the inter-regional accessibility to company R&D seems to be important in explaining variations in the number of export links among Swedish municipalities.

Table 4.3a Effects of accessibility to company R&D on the number of export destinations

Commodity Group	Intra-regional access to company R&D	Inter-regional access to company R&D	Size	Constant	R^2
All commodities	0.0923* (3.032)	0.3951* (4.040)	0.0002* (2.860)	50.930* (19.111)	0.40
1. Agricultural and food products	0.0248* (2.446)	0.1048* (2.371)	0.0001* (10.765)	4.1351* (5.324)	0.52
2. Mineral based products	0.0188 (1.002)	0.1279* (2.550)	0.0002* (4.352)	6.6376* (5.673)	0.39
3. Chemical products	0.0779* (3.001)	0.2756* (2.783)	0.0002* (4.611)	18.739* (8.886)	0.37
4. Products of wood and paper	0.0483 (1.304)	0.1184 (1.833)	0.0002* (7.960)	21.851* (11.398)	0.40
5. Products of textile, leather and fur	0.0476* (2.535)	0.1183 (1.922)	0.0002* (3.988)	10.237* (7.546)	0.43
6. Metal products	0.0068 (0.300)	0.1824 * (2.606)	0.0002* (3.971)	19.526* (10.886)	0.30
7. Industrial machinery and arms	0.0695* (2.629)	0.3118* (3.048)	0.0002* (2.771)	29.781* (11.638)	0.36
8. Motor vehicles and transport equipment	0.0138 (0.703)	0.1777* (3.563)	0.0001* (2.870)	8.8422* (6.326)	0.43
9. Telecom and electronics	0.1607* (6.510)	0.3236* (3.745)	0.0002* (2.571)	19.083* (8.742)	0.51
10. Furniture, arts and sport articles	0.0153 (0.775)	0.1338* (2.651)	0.0002* (4.408)	10.818* (8.576)	0.37

t-values in parenthesis. * denotes significance at 5%.

The regressions including the accessibility to university R&D (table 4.3b) yields similar results as those including company R&D, both regarding intra-regional and inter-regional accessibility. Those groups containing the most R&D intensive products have a positive impact of intra-regional accessibility whereas the inter-regional accessibility seems to be important in explaining regional differences in the number of export destinations for all commodity groups but the groups containing products of wood, paper textiles and metal manufactures. Again, these results indicate that inter-regional accessibility is an important factor in explaining regional export diversity.

Table 4.3b Effects of accessibility to university R&D on the number of export destinations

Commodity Group	Intra-regional access to university R&D	Inter-regional access to university R&D	Size	Constant	R^2
All commodities	0.0087* (1.564)	0.0452* (4.297)	0.0003* (2.926)	52.266* (19.396)	0.40
1. Agricultural and food products	0.0034 (1.746)	0.0012* (2.459)	0.0001* (10.439)	4.444* (6.131)	0.52
2. Mineral based products	0.0017 (0.507)	0.0130* (2.288)	0.0002* (4.134)	7.234* (6.074)	0.38
3. Chemical products	0.0112* (2.357)	0.0286* (3.156)	0.0002* (2.646)	19.881* (9.823)	0.37
4. Products of wood and paper	0.0039 (0.660)	0.0137 (1.888)	0.0003* (3.816)	22.267* (11.492)	0.39
5. Products of textile, leather and fur	0.0044 (1.221)	0.0115 (1.951)	0.0002* (4.147)	10.851* (8.212)	0.42
6. Metal products	-0.0018 (-0.427)	0.0146 (1.868)	0.0002* (3.696)	20.672* (11.088)	0.29
7. Industrial machinery and arms	0.0051 (0.888)	0.0360* (3.468)	0.0003* (2.826)	30.830* (11.930)	0.35
8. Motor vehicles and transport equipment	-0.0019 (-0.675)	0.0196* (3.233)	0.0002* (2.926)	9.534* (6.403)	0.42
9. Telecom and electronics	0.0198* (3.823)	0.0418* (4.195)	0.0002* (2.933)	19.813* (9.408)	0.50
10. Furniture, arts and sport articles	-0.0003 (-0.103)	0.0137* (2.638)	0.0002* (4.315)	11423* (9.115)	0.37

t-values in parenthesis. * denotes significance at 5%.

A final topic considered in this section is the explanatory power of the different specifications of the estimated regression models. The highest explanatory power is obtained when applying the model on the number of exporting firms (table 4.2a and 4.2b) An important remark is that the R-squared value is almost as high in the case of university R&D (0.92 in the regression including all commodities) as in the case of company R&D (0.93 in the regression including all commodities) in spite of the fact that none of the R&D accessibility variables is significant in the regressions containing university R&D. This indicates that the variable controlling for municipality size makes the strongest contribution to the explanatory power of the model. This conjecture is also supported by the strong significance of the estimated coefficient for municipality size in all regressions presented above. The lowest explanatory power of the model is obtained when the dependent variable is the number of export destinations table (4.3a and 4.3b). In these regressions the r-square values ranges from 30 to 52 percent, whereas the regressions focusing on the number of export products yields R-square values between 44 and 75 %.

5 Summary and conclusive remarks

This paper examines the influence of accessibility to R&D on the diversity of export from Swedish municipalities. A theoretical model with fixed R&D cost predicts that spatial knowledge spillovers generates external economies of scale in R&D activities and these external effects increases the innovative capacity in regions that have relatively high accessibility to R&D. Moreover, the model implies that the higher is the efficiency of R&D labs the larger is the number of exported goods in the region. Hence, 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 hypothesis that regional accessibility to R&D facilities in the private business sector, on the one hand, and university research departments on the other hand increases the export diversity in regions is tested in a cross-regional regression analysis based on municipality export data. A municipality is a local administrative area, yet a growing number of studies in the field of regional science emphasize the role of the functional urban region in explaining regional patterns of knowledge production and diffusion. Consequently, the local accessibility can not be expected to play a major role in explaining variations in the export diversity at the municipality level, rather it is the accessibility to R&D activities within the functional region that is important. Moreover, knowledge cannot be regarded as a spatially trapped resource for what reason also inter-regional accessibility to R&D has to be taken into account.

At the aim of capturing the importance of both intra- and inter-regional knowledge flows, the empirical analysis includes two measure of R&D accessibility. The first contains the intra-regional accessibility, which is the sum of the local accessibility and the accessibility to all other locations within the own functional region, and the second is the inter-regional accessibility, which contains the accessibility to all locations outside the own functional region. We suggest that R&D can be measured by man-years of working time devoted to R&D and that the number of man-years should be discounted by travel times to reflect the frictions in the knowledge networks that affect the accessibility to knowledge.

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. Regressions are estimated both for the total export and for the export divided into ten commodity groups. The empirical results indicate that the all 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, i.e. chemical products, telecom and electronics and industrial machinery. Furthermore, the inter-regional accessibility to company R&D have a significant positive impact on the number of export goods and the number of export destinations and these influences extend also to mineral based products, agricultural products and food as well as metal products.

In the case of university R&D accessibility, the empirical results are weaker, in particular for the number of exporting firms where none of the regression estimates show any significant influences. When regressing the university R&D accessibility variables on the number of export goods the inter-regional accessibility is of significant importance in explaining regional variations for most product groups. Yet, the intra-regional accessibility only has significant effects on the number of goods being exported from a municipality in two commodity groups, namely the telecom and chemicals. Focusing on the number of export destinations, these regressions yield similar results as those focusing on the number of export goods; the inter-regional accessibility to university research staff has a significant impact in seven out of ten commodity groups, whereas the intra-regional accessibility is of significant importance in explaining regional variations in the export diffusion only for the most R&D-intensive groups of products, namely telecom and chemicals.

These results contrast previous empirical evidences of the importance of intra-and inter-regional knowledge accessibility for regional innovative capacity. When analysing regional patterns of patent production, several studies concludes that it is differences in the intra-regional accessibility to knowledge that explains differences in patent records between regions (Jaffe, 1989, Jaffe, et al. 1993, Gråsjö, 2005, among others). The outcomes of this empirical analysis show that when knowledge is translated from a blueprint to large-scale production for export markets, geographical proximity is less important. Rather, knowledge seems to be diffused by intra-firm and intra-industry linkages. Still, for the most technologically advanced types of goods geographical proximity is of significant importance for expanding the regional export base, both in terms of the number of exported goods, number of exporting firms, and the number of export destinations.

The significance and extensions of inter-regional linkages for knowledge diffusion is of great importance in understanding how knowledge networks are created and how these networks influences regional patterns of production and export. We believe that this is an important issue for further research.

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Appendix

Table A1. Descriptive Statistics, Independent variables

Variable	Mean	Std.Dev.	Minimum	Maximum
Intra-regional access to university R&D	167.44	454.24	0.0000	3453.93
Inter-regional access to university R&D	96.49	164.15	0.0005	1022.65
Intra-regional access to company R&D	27.81	73.46	0.0000	680.68
Inter-regional access to company R&D	13.88	19.34	0.0001	168.15
Size	31039.47	58980.74	2607.00	758754.00

Table A2. Correlation Matrix for independent variable

	Intra-reg. access. To university R&D	Intra-reg. access. to company R&D	Inter-reg. access. to university R&D	Inter-reg. access. to company R&D	Municipality population
Intra-reg. access. to university R&D	1.0000	0.9009	0.2428	0.1328	0.6498
Intra-reg. access. to company R&D	0.9009	1.000	0.2678	0.0868	0.6651
Inter-reg. access. to university R&D	0.2428	0.2678	1.000	0.7902	0.1631
Inter-reg. access. to company R&D	0.1328	0.0868	0.7902	1.000	0.1273
Municipality population	0.6498	0.6651	0.1631	0.1273	1.000