Acknowledgements

At last, I have reached the destination of a journey that started about ten years ago. I was then an undergraduate student at JIBS and had begun to realize that economics was a lot more complicated than I expected. Fortunately, I happened to be in a group of brainy, diligent and friendly students, who formed a springboard for discussions about societal questions in general and economic issues in particular. I am very grateful to these people for the intellectual stimulation I’ve got from our talks and, more importantly, for our friendship. Some of these students later became my colleagues in the PhD program. Before applying to the PhD program, however, I first experienced the pleasures and pains of doing original research work when writing my bachelor’s thesis, which was partly tutored by Lasse Pettersson, who has taken care of my career ever since. First he recommended me as a research assistant to Professor Bo Södersten, then encouraged me to apply for the PhD Programme, before drafting me to my current position at the Swedish Board of Agriculture. I would like to give a very special thank you to Lasse for his encouragement and support over the last ten years. I am also grateful to Bo Södersten for making me confident enough to take on the challenge of writing this dissertation and for his tutorial efforts in the first steps of this work.

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Sara Johansson
Abstract

The purpose of this thesis is to analyze the influence of knowledge on the export performance of firms in different regions. More specifically, this study focuses on the impact of knowledge on the structure of regional export flows, in terms of horizontal and vertical product differentiation, as well as the geographical distribution of export flows. The thesis consists of four separate papers, which contribute to the overall analysis of knowledge, product differentiation and international trade in different ways. The second chapter presents a study of the effects of regional accessibility to R&D on the diversity of export flows with regard to goods, firms and destination markets. Chapter 3 provides an empirical analysis of vertical product differentiation, i.e. differentiation in terms of product quality, and examines the impact of educated labor and R&D on regional comparative advantages in goods of relatively high product quality. Chapter 4 contains a study of how the regional endowment of highly educated workers affects the structure of export flows, i.e. how the endowment of educated workers impacts on the number of product varieties exported, the average price per variety and the average quantity shipped out. The final chapter presents a micro-level analysis of firms’ propensity to participate in international markets and their propensity to expand export activities by introducing new export products or establishing export links with new destination countries.

In summary, the empirical results of this thesis convey the message that regional accessibility to knowledge, embodied in highly educated labor and/or developed through R&D activities, plays a fundamental role in shaping the content and structure of regional export flows. More specifically, the present empirical observations suggest that the regional endowment of knowledge stimulates the size of the export base in terms of exporting firms and number of product varieties. The recurring significance of the accessibility variables in explaining spatial export patterns show that the knowledge endowment of a region must be defined in such ways that it captures sources of potential knowledge spillovers from inside as well as outside its own regional boundaries. This outcome shows that regional variations in knowledge endowments originate both in the actual spatial distribution of a nation’s knowledge labor across regions, and in regional differences in the geographical accessibility to internal and external knowledge labor.
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Chapter 1: Introduction and Summary of the Thesis

1. Introduction

Specialization and trade have been the subjects of scientific discussions for more than 2000 years. Efficiency gains from specialization were discussed already among the disciples of Socrates in ancient Greece, e.g. Plato and Xenofon. In economic science the issue of trade and specialization dates back to Adam Smith (1776) followed by the classical contributions of David Ricardo (1817), Heckscher (1919) and Ohlin (1933). Given the long presence of this topic in the history of economic thought, one might think that contemporary economists have nothing further to add to this subject. There are, however, aspects of specialization and international trade that are still puzzling to scholars in economics, disputed among politicians, challenging to policy makers and, indeed, experienced by billions of workers and consumers around the globe.

Consumers all over the world are anxious to buy goods and services at the lowest possible price. Workers are, on the other hand, concerned with the possibility of earning an income with a relatively high purchasing power out of the production of these goods and services. The strive for a simultaneous accomplishment of these two, somewhat contradicting, objectives has put innovation and productivity growth at the focal point of many researchers, policymakers, firms and individuals. One fundamental asset in this context is knowledge. There is, nowadays, a general belief that competitive advantages of firms, regions and nations in the global economy are strongly associated with knowledge-related factors that strengthens firms’ ability to develop new products or new production techniques. As a consequence, advanced industrial countries are transforming themselves into knowledge-based economies, which are characterized by their use of knowledge in creative processes (Andersson, 1985). How does an increased knowledge intensity of
contemporary economies affect their specialization and trade patterns? This thesis is an attempt to shed some further light on this issue.

The purpose of this thesis is to analyze the influence of knowledge on the export performance of firms in different regions. More specifically, this study focuses on the impact of knowledge on the structure of export flows from regional units, in terms of horizontal and vertical product differentiation, as well as the geographical distribution of export flows. The specific attention paid to knowledge in these analyses requires a regional rather than national analytical perspective. The boundaries of nations have been the predominating principal of spatial delineation in studies of international trade and most empirical trade analyses are based on country-level data (although there is a growing vein of recent empirical work that is based on firm-level data). A recurrent finding in this empirical literature is that trade costs have a considerable impact on international trade patterns and national boarders contribute significantly to such costs. Still, when analyzing trade patterns on the national level several aspects of knowledge cannot be fully understood. There are two particular characteristics of knowledge as an input factor that makes the nation inappropriate as a spatial unit of analysis. First, knowledge is to some extent a public good that may spill over between economic agents. Second, a large mass of empirical studies have shown that these knowledge externalities are geographically localized and as a consequence knowledge labor tends to be spatially concentrated or, at least, unevenly distributed across space within nations. Knowledge labor is a necessary input mainly in complex production processes and R&D activities. The geographical concentration of knowledge labor to certain local labor markets thus results in regional specialization patterns that further stimulate the spatial concentration of knowledge labor. Accordingly, regional patterns of specialization evolve slowly in a self-reinforcing way over time. This implies that knowledge labor tends to be semi-fixed at the level of local labor markets. Moreover, these long-term spatial dynamics imply that the region is a functional spatial unit, whose borders are determined by spatial interaction patterns (Ohlin, 1933; Johansson, 1993; among others). In contrast to the borders of nations, which are political constructions, the geographical extension of functional regions is determined by patterns of spatial interaction.

Another factor that reduces the significance of national borders in analyses related to knowledge and technology diffusion is the growing importance of multinational company groups in global production and trade. Multinational

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1 Recent evidence on border effects is presented by (among others) Nitsch and Wolf (2009) and Coughlin and Novy (2009).
enterprises (MNE) are overrepresented in R&D and knowledge-intensive industries and are responsible for a significant share of global R&D expenses (Johansson and Lööf, 2008). The spatial fragmentation of R&D and production activities within multinational company groups implies that the location decision of MNEs play an important role in the transmission of knowledge as well as in the development of local knowledge-intensive activities. Such location decisions are an issue of regional rather than national characteristics (McCann and Mudambi, 2005). In view of this, nations are misleading spatial units in the context of knowledge endowments. Instead, this thesis goes one step further by using information on municipalities, which are sub-areas of a functional region. Thus, the analyses focus on export flows from municipalities and examine these flows from the perspective of knowledge resources in the municipality itself and in the surrounding municipalities inside and outside the same functional region.

The thesis consists of four separate papers, which contribute to the overall analysis of knowledge, product differentiation and international trade in different ways. The second chapter presents a study of the effects of regional accessibility to R&D on the diversity of export flows with regard to goods, firms and destination markets. The empirical study builds on theoretical work on trade in differentiated products and emphasizes the role of R&D and spatial knowledge spillovers for firms’ ability to develop differentiated products and succeed in export markets. Accordingly, the study also relates to product cycle models of trade as well as theories of economic agglomeration. Chapter 3 provides an empirical analysis of vertical product differentiation, i.e. differentiation in terms of product quality, and examines the impact of educated labor and R&D on regional comparative advantages in goods of relatively high product quality. This study draws on theoretical and empirical contributions, which emphasize the role of human capital endowments and technological advantages in the specialization and trade in goods that are differentiated in a vertical quality dimension. Chapter 4 contains a study of how the regional endowment of highly educated workers affects the structure of export flows, i.e. how the endowment of workers with university education impacts on the number of product varieties exported, the average price per variety and the average quantity shipped out. This empirical investigation relates to traditional as well as modern trade theories since it addresses both the question of factor endowments and the issue of increasing returns in a context of horizontal and vertical product differentiation. The final chapter of this dissertation presents a micro-level analysis of firms’ propensity to participate in international markets and their propensity to expand export activities by introducing new export products or establishing export links to new destination countries. This study is based on two strands of theoretical work: theories emphasizing the export market
The four individual chapters in this thesis relate to several areas in the theory of international trade. As indicated above, a recurrent perspective in these four chapters is that of factor endowment as a determinant of competitive advantages. In this sense, the thesis builds on the traditional trade theory of factor proportions. The focus on knowledge as a localized production factor that induces comparative advantages makes it meaningful to consider theories based on locational technology differences, products cycles and associated location dynamics. Moreover, as knowledge-intensive production tends to bring about highly processed and differentiated goods, this thesis is strongly related to modern trade theories emphasizing increasing returns to scale and monopolistic competition. Another common feature of the four studies in the thesis is that the empirical analyses address the importance of spillover effects in knowledge intensive production. This focus is due to the particular nature of knowledge, being a production factor that, to some extent, is a public good. As a consequence, the analyses have to consider geographical dependencies in the production system, with reference to the new economic geography. The last chapter of the thesis is based on the most recent theoretical advances in the field of international trade, which consider the behavior of heterogeneous firms and productivity responses of firms and industries to firms’ participation in international markets. The next section in this introductory chapter gives a brief review of seminal theoretical contributions to the field of international trade theories. Since several of these theoretical advances were strongly dependent on developments in other fields of economic theory, e.g. location theory, industrial organization and consumer theory. Such theoretical contributions with relevance to the development of trade theory are also briefly discussed in the next section. Relevant empirical literature on international trade is mainly presented in the subsequent chapters and is not reviewed in this introductory chapter.

The application of international trade theories to regional data requires specific concern with regard to the characteristics of the factors under investigation. Section 3 discusses the special features of knowledge as an input factor. The geographical implications of including knowledge as an input in the production system are discussed in Section 4. Section 5 extends the discussion of how international trade can be analyzed in a regional context and presents the data used in the empirical analyses of this study. This section also presents some descriptive statistics that give the reader a picture of the geographical distribution of employment, educated labor and export activities in Sweden. Section 6 summarizes the four separate studies of the thesis and makes explicit how they contribute to existing literature.
Introduction and Summary of the Thesis

The section also clarifies which are the main findings and which are the pertinent policy implications.

2. Theories of specialization and trade

The origins of the ideas about specialization and trade are most often attributed to Adam Smith (1776). To understand how the economy works, Adam Smith studied the fundamental characteristics of human behavior. In his classical work *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776) he concluded that the propensity of human beings to bargain and trade with each other is the basic condition for division of labor and gains from specialization. These thoughts were put into the context of international exchange by David Ricardo (1817).

2.1 Comparative advantages and factor proportions

Ricardo developed Smith’s ideas about the gains from specialization and presented the theory of comparative advantages (1817), which remains practically unchanged in today’s textbooks on international trade. Ricardo showed that when there are differences in productivity across countries and sectors, there are welfare gains to all countries from specialization and trade. These gains, are, however, not necessarily equally distributed across the trading countries.

The distribution of gains from trade across different groups of factor owners was an issue of interest to Eli F. Heckscher, a hundred years later. Heckscher’s perhaps most renowned paper in economics is about the effects of international trade on income distribution\(^2\). This paper became the point of departure for the traditional trade theories based on cross-country differences in factor proportions. Heckscher starts by discussing why comparative costs differ between countries. Ricardo simply assumed that comparative costs differ because of productivity differences between countries. Heckscher explicitly assumes that production technology in a given sector is identical in all countries and argues that differences in comparative cost arise due to differences in factor prices. These factor price differences can only occur as a result of dissimilarities in relative factor abundance across countries. International trade is, accordingly, a direct result of differences in the relative scarcity of the factors of production between one country and another. Since the cost of producing goods that are intensive

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\(^2\) "Utrikeshandelns verkan på inkomstfördelningen". Ekonomisk Tidskrift, vol. 21, 1919.
in a country’s abundant factors will be comparatively low, each country tends to export these commodities that, in the production, make use of relatively large amounts of factors with which the country is relatively well endowed. This is the conclusion that later became the *Heckscher-Ohlin theorem*. Heckscher argues further that such trade patterns will expand until the relative scarcity of factors has leveled out between countries. With a fixed and immobile supply of production factors and identical production technology, the final effect of international trade is an equalization of factor prices\(^3\). This adjustment of factor prices will alter the distribution of income across owners of different production factors.

Heckscher’s thoughts about the causes and consequences of international trade were further developed by his student, Bertil Ohlin. In his PhD dissertation\(^4\) Ohlin puts Heckscher’s ideas into a general equilibrium framework, which resulted in a more general model of spatial exchange where Heckscher’s assumption of immobile factors could be partly relaxed\(^5\). The factor-proportions theory came to dominate the theoretical work in international trade until the 1970s. Several scholars contributed to the formalization of the Heckscher-Ohlin theory in the 1940s and 1950s, notably Samuelson (1948; 1949) and Jones (1956). However, empirical analyses of international trade flows presented results that conflicted with the Heckscher-Ohlin theorem. In a famous study, published in 1953, Leontief showed that U.S. imports were more capital-intensive than U.S. exports. Later, this so-called *Leontief paradox* has been confirmed in numerous studies of international trade flows\(^6\).

### 2.2 Technology and trade

The failure of the Heckscher-Ohlin theorem to conform to real world data resulted in a renewed interest in theories focusing on technology differences as a source of cost advantages. Posner (1961) made a pioneering attempt to

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\(^3\) This is the factor price equalization theorem. Factor price equalization can, in this framework, occur only if specialization is incomplete, production technology is identical in all countries and prices of traded goods are the same in all countries, i.e. if there are no trade barriers, no transport costs and no transaction costs.

\(^4\) *Interregional and International Trade* (1933)

\(^5\) Indeed, Ohlin devoted considerable attention to the issue of factor mobility and made a significant contribution to international economics with his analyses of international capital flows.

\(^6\) In the 1960s and 1970s considerable effort was devoted to empirical testing of the factor-proportions theory and along with results that conflict with the Heckscher-Ohlin theorem there are also some studies that support this theorem. See for example Torstensson (1992) for an overview of empirical studies on this topic.
explain trade between countries with very similar economic conditions. Posner suggests that trade between similar countries may be caused by sector-specific technological changes, which results in comparative cost advantages in the country that develops new technologies during the "laps of time taken for the rest of the world to imitate one country’s innovation."

Posner presented a dynamic model of comparative advantages that relies on the analytical distinction between new and old processes or products. In this way, Posner introduced a Schumpeterian view of international trade where, comparative advantages are a dynamic rather than a static phenomenon.

Posner’s ideas gave rise to essentially two different versions of product life cycle models of international trade. The version by Hirsch (1967; 1975) is well attuned to the multi-factor version of the Heckscher-Ohlin model as it suggests that factor intensities change over the product cycle as do the patterns of trade. When a product is introduced it is intensive in skilled labor, and countries that are well endowed with skilled labor are, accordingly, net exporters of newly introduced products. When products and production technologies become more standardized their skill-intensity decreases and production moves to countries that are relatively abundant in unskilled labor. These countries tend to be net exporters of standardized goods. The other version of the product cycle theory is attributed to Vernon (1966), who argued that the production of new products must be located near its market. The largest demand for new products are found in high-income countries and, consequently, high income countries tend to export newly introduced products whereas comparative cost advantages will determine the location of production once the product has matured.

The notion that proximity to large markets is crucial for cost advantages and competitiveness was further emphasized in spatial versions of the product life cycle model. Such models rely on similar arguments as those put forward by Vernon and Hirsch, but also stress the importance of market size and other spatial characteristics. Hence, spatial product cycle theories adhere as much to location theory, which builds on the pioneering work of von Thünen (1826), Weber (1909), Hotelling (1929) and Christaller (1933), as to product life cycle models. Andersson and Johansson (1984a; 1984b; 1998) contributed to this vein of literature with a spatial framework for analyzing regional comparative advantages in a dynamic context. They argue that entry of new products tend to occur in highly developed regions that are knowledge abundant in terms of R&D personnel and high skilled workers. Regions with such characteristics are most often metropolitan regions where markets for factors as well as consumer goods are dense.

7 Posner (1961), p. 323
Spatial implications of the product life cycle in the context of international specialization and trade are analyzed in models of technology gaps and the phenomena of innovation and imitation. Early works in this field are those by Krugman (1979b; 1986), Grossman and Helpman (1991a), among others. The fundamental assumption in the models is the existence of location-specific factors generating comparative advantages in the production of innovative products containing novel product attributes. Such factors may include national investments in education and R&D, the size of national knowledge stocks or differences in other social factors, for example, entrepreneurship. The implications of such models are, on the one hand, consistent with the Heckscher-Ohlin theorem in the sense that dynamic comparative advantages depend on fixed national resources. On the other hand, these models also relate to the endogenous growth theory that developed in the same period, which emphasizes the role of investments in knowledge and technology in countries’ growth performance. Dynamic models of technology and trade bring out similar predictions: through purposeful investments in knowledge and R&D, countries may shape new patterns of comparative advantages that alter existing patterns of international trade (Grossman and Helpman, 1991a). However, the development of such innovation-based models of international trade was strongly dependent on advances in other fields of economics, which made possible the relaxation of the prevalent assumption of perfect competition in international trade.

2.3 Monopolistic Competition and the New Trade Theory

Empirical studies of international trade during the 1960s and 1970s revealed that the exchange of similar goods between similar countries constituted the predominant share of international trade flows. The Heckscher-Ohlin theory is, in principle, applicable to inter-industry trade and it failed to present satisfactory explanations to trade of the intra-industry type. Early product life cycle theories provided some explanations to why similar goods were shipped between similar countries but not until the seminal contributions by Krugman (1979a; 1980), Dixit and Norman (1980) and Lancaster (1980) was there a general equilibrium model that could explain the occurrence of intra-industry trade. The novelty of this new approach to international trade was the relaxation of the assumption of constant returns to scale. Although many

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The contributions by Romer (1986) and Lucas (1988) are often considered to be the most influential of the early works in endogenous growth theory.
economists understood that increasing returns to scale could explain international trade flows, there was no formalized model that could handle firm level scale economies until the end of the 1970s\(^9\). As pointed out by Krugman (1994), the main obstacle to formal modeling of increasing returns in trade theory before the late 1970s was the prevalent idea of perfect competition being a necessary assumption for the formulation of economic models of satisfactory tractability. In general, increasing returns are inconsistent with perfect competition and what later became known as the “New Trade Theory” was preceded by significant advances in the fields of industrial organization and consumer theory.

The concept of monopolistic competition had been present in the economic literature for at least fifty years before trade models featuring increasing returns and product differentiation were developed in the late 1970s. Before the 1930s, economic analysis basically considered only two market forms: perfect competition and pure monopoly. Other market forms were viewed as hybrids between these two polar cases. Marshall (1890) was one of the first scholars recognizing that other market forms were not simple combinations of perfect competition and monopoly\(^10\). Marshall called such imperfect markets ‘Special Markets’. This type of market structure was more carefully analyzed by Chamberlin and Robinson in the 1930s. In particular, the work by Chamberlin (1933) revolutionized the view of market structures as he showed that markets characterized by monopolistic competition might also reach a state of equilibrium. Chamberlin’s analysis was based on his observations that many markets consisted of products that are physically similar but economically differentiated in the sense that they have some unique attributes that appeal to different customers. As a group, however, buyers have preferences for all types of products. Consequently, each firm in the market has its own perceived demand curve. The monopolistic features of this type of market are all elements that distinguish one product from other products and give the firm some market power. The presence of a large number of firms and the possibility of entry and exit provide on the other hand, competitive elements in such markets. Chamberlin showed that these are sufficient conditions for a partial market equilibrium where firms make zero profits.

In spite of the elegance of Chamberlin’s model of monopolistic competition, it had little influence on economic theorizing in the coming decades. As late

\(^9\) Still, a number of previous studies presented general-equilibrium analyses of trade in the presence of external scale economies (Matthews, 1949; Melvin, 1969; Kemp and Negishi, 1970, among others)

\(^{10}\) The special nature of imperfect markets had previously been analyzed in duopoly models developed by Cournot, Bertrand and Edgeworth in the second half of the nineteenth century.
as 1967, Harry Johnson points out that: “The theory of monopolistic competition has had virtually no impact on the theory of international trade.” ¹¹ Some ten years later, however, a second wave of literature on monopolistic competition, initiated by a re-formulation of Chamberlin’s model by Dixit and Stiglitz (1977) cleared the way for what later became known as the ‘New Trade Theory’. Brakman and Heijdra (2004) point out that the success of this second monopolistic competition revolution is largely due to the success of Dixit and Stiglitz in formulating a canonical model of Chamberlinian monopolistic competition that is both easy to use and captures the key aspects of Chamberlin’s model. These aspects include monopolistic competition, scale economies and endogenous product variety. The outcome of the model by Dixit and Stiglitz is similar to that of Chamberlin’s original model, i.e. an industry equilibrium where the monopoly power allows firms to recapture fixed costs while free entry of new firms reduces monopoly profits to zero. In addition to this, Dixit and Stiglitz model also presents a market solution providing an equilibrium number of product varieties that is socially optimal given product-specific scale economies on the one hand, and utility arising from product diversity on the other hand.

The Dixit and Stiglitz assumption that utility originates from product diversity per se is an important contribution to Chamberlin’s original model. Chamberlin’s assumptions about consumer behavior followed those of contemporary spatial location models, i.e. each consumer has a most preferred variety and only consumes one variety. Dixit and Stiglitz assume that products are symmetric and enter into a CES utility function, where the overall utility is separable and homothetic in its arguments¹². These properties of the utility function allow for utility optimization through a two-stage budgetary process where consumers first allocate budget shares to separate groups of commodities and then decide how to best use each budget share on commodities within each category (Morishima, 1973). By assuming these specific properties of utility functions, Dixit and Stiglitz tackled one of the most recurrent comments on Chamberlin’s model, namely that chamberlinian monopolistic competition would lead to too much product diversification (Dixit and Stiglitz, 1977).

The idea of a utility function that apparently concerns consumption of physical goods might have other arguments than if the good itself was not a completely new thought by the end of 1970s. In 1966, Lancaster launched a

¹¹ Johnson (1967), p. 203
¹² The separability property of utility function was examined in previous theoretical work by Hicks (1956) and Morishima (1959).
new approach to consumer theory, where utility is derived from the specific characteristics and properties of a good rather than from the good itself (Lancaster, 1966a). Lancaster states that goods are composed of a set of characteristics, which are the arguments of utility functions. Goods containing the same set of characteristics compose a commodity group, in which product varieties are distinguished by differences in the proportions of the characteristics combined.

The link between trade theory and industrial organization was first proposed simultaneously by Dixit and Norman (1980), Krugman (1979a; 1980) and Lancaster (1980) and it has been suggested that it was the contribution by Dixit and Stiglitz (1977) and Lancaster (1966a, 1966b; 1975) that provided the foundations for a theoretical framework for analyzing economies of scale and product differentiation in a general equilibrium setting. Krugman applied the basic structure of Dixit and Stiglitz’s model of monopolistic competition when formulating a model of trade in the presence of increasing returns and product differentiation published in a series of papers (Krugman, 1979; 1980 and 1981). The basic idea in this model is that increasing returns to scale can explain trade between similar countries. Accordingly, trade does not have to be a result of cross-country differences in technology or factor proportions, but simply a way of extending the market and allowing full exploitation of scale economies. The effects of this type of international trade are similar to the effects of labor force growth or productivity growth in traditional models (Krugman, 1979).

In spite of the fact that Krugman’s model of international trade was unable to predict which country that produced which goods, the model succeeded to explain the growing share of intra-industry trade among advanced countries in a mathematically tractable way. Inherent advantages to specialization became widely accepted as a cause of intra-industry trade. Trade theories based on increasing returns and monopolistic competition became the “New Trade Theory”, generally regarded as a complement to traditional trade theory, the core theorem of which still applies to inter-industry trade. The early works of the new trade theory stimulated further analyses of trade issues in the context of monopolistic market structures in the beginning of the 1980s, including attempts to integrate the new trade theory with the standard Heckscher-Ohlin approach (Dixit and Norman, 1980; Helpman, 1981; Favley 1981; Favley and Kierzkowski, 1987). Other trade issues were also addressed, for example, the role of intermediate goods (Ethier, 1982), non-traded goods (Helpman and Krugman, 1985) and market size effects (Krugman, 1980; Helpman and Krugman, 1985).
2.4 The new economic geography and the economics of agglomeration

The impact of the new trade theory on research in international economics from 1980 and onwards can hardly be over-stated. As described above, the new trade theory provided illuminating answers to some old issues in international economics, e.g. the patterns of trade and effects of trade liberalization. It was particularly successful in explaining the occurrence of intra-industry trade and had an important role as theoretical underpinning of the gravity models that became popular in empirical trade research in the 1970s (Brülhart and Kelly, 1999). The new theoretical approaches were also applied to questions that had not been addressed previously. One such issue was the rational for multi-national corporations, which could not be explained in a framework based on perfect competition (Neary, 2004). Helpman (1983) made a first attempt to demonstrate that economies of scope and/or vertical integration led to the emergence of multi-activity firms such as multinational corporations. Another issue to the new trade theory was different aspects of industry agglomeration. Krugman (1980) showed that transport costs generate a ‘home market effect’, which implies that a country with a relatively large home market for a certain good tend to be a net exporter of that good. This proposition is very intuitive since, in the presence of scale economies and transport costs, there is an incentive to concentrate production of a good near its largest market, even if the good is also demanded in other markets. In 1991, Krugman presented a new version of the 1980 model, which allowed for factor mobility. When factors are mobile, the home market effect generates a cumulative process of industry concentration: growth in the number of firms in one country will result in increased demand for labor in that country, which leads to in-migration that stimulates aggregate demand, which attracts even more firms, and so on. As pointed out by Kilkenny and Thisse (1999), the introduction of products differentiated in characteristics space and the associated relaxation of perfect competition induced agglomeration forces to the theoretical frameworks of the new trade theory as firms can choose to locate in ways that minimize their transport costs. The numerous contributions to new trade theory that emphasize the forces of agglomeration and dispersion are now referred to as the new economic geography.

Indeed, the economics of agglomeration has a long tradition and one of the earliest giants in this field is Marshall (1890). Marshall argued that firms located in a cluster of other firms operating in the same industry may be more efficient than an individual firm in isolation. Marshall identified three sources of such external economies of scale: specialized suppliers, labor
market pooling and knowledge spillovers. These factors are still the subject of investigation in contemporary research in agglomeration economics. An early contribution to the issue of agglomeration in the context of trade was made by Ohlin (1933), who claimed that international trade theory was, in fact, a part of the general location theory that put equal emphasis on the immobility of goods and factors. Ohlin (1933) stresses that many factors are not perfectly mobile, not even within small regions, and argues that the location of production within regions is a problem akin to that of the distribution of production between regions. Besides differences in factor proportion, Ohlin also recognizes that scale economies provide an alternative reason for trade specialization. Furthermore, Ohlin emphasizes the role of efficiency gains due to a concentration of firms in a certain regions. According to Ohlin, agglomeration of economic activity is a consequence of increasing returns to scale which can be internal to the individual firm or external to all firms in a given industry or location. Ohlin made a useful distinction between agglomeration economies due to urbanization and agglomeration economies arising from localization of production activities (Ohlin 1933; Hoover, 1937). Localization economies arise due to the concentration of one particular industry in a certain geographical area, whereas urbanization economies arise due to spatial concentration of overall economic activity. Accordingly, urbanization economies are external economies of scale related to the size and diversity of the market, whereas localization economies refer to external economies of scale related to the size of the local industry.

As mentioned above, increasing returns were well acknowledged by trade theorists before the 1970s, but not until the end of that decade was the implication of increasing returns thoroughly analyzed in a general equilibrium context of international trade. As Ohlin had already called attention to, the advances of trade models of increasing returns articulated their relatedness to location theory and the issues of agglomeration economies. A fundamental thought underlying Krugman’s analysis of trade and agglomeration had been previously formulated by Mills (1972): with constant returns and perfect competition there is no reason why productive activities can not be located in small areas near where consumers live and serve local demand only. Krugman and Venables (1995) develop this thought and conclude that the constant returns – perfect competition paradigm is unable to cope with the emergence and growth of large economic agglomerations. Increasing returns is a necessary condition for

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13 Ohlin regards returns to scale as a problem related to the limited divisibility of factor of production (that is resulting from the assumption of full utilization of all factors) whereas agglomeration economies can be regarded as a limitation of the divisibility of organizational factors.
explaining economic agglomeration that is not associated with physical geographical attributes. Among spatial economists, however, this was already a conventional wisdom. Location theorists stressed the classical trade-off between increasing returns and transport costs in the spatial economy already in the 1950s (Fujita and Thisse, 2002). The novelty of the new economic geography lies rather in the elaboration of models that, unlike most traditional spatial analyses, are complete general-equilibrium models that clearly derive aggregate economic phenomena from the behavior of utility-maximizing individuals. A number of theoretical contributions have been added to this area, of which many address the interaction between transport cost, scale economies and the mobility/immobility of production factors.

Empirical testing of the new economic geography framework provides convincing evidences supporting the hypothesis of a home market effect both in regional and international data. Still, the dynamic implications of the new economic geography framework appear to be more appropriate in a regional context (Davis and Weinstein, 1999). Moreover, most empirical studies in this field acknowledge the difficulties of distinguishing between scale effects (internal or external) and location advantages due to trapped production factors (Ellison and Glaeser, 1997, Redding 2010, among others). In addition to the challenge of separating increasing returns from natural comparative advantages, current empirical research struggles with distinguishing between different sources of agglomeration (Ellison, Glaeser and Kerr, 2007, among others).

2.5 Recent advances in trade theory

In an influential paper published in 2003, Melitz extends Krugman's model from 1980 by relaxing the assumption that all firms have the same production function and, accordingly, identical cost functions. Melitz resumes the idea that firms are heterogeneous and have different margins between market price and average cost. This idea was discussed already by Heckscher (1924), who suggested that differences in firms' production functions explain the coexistence of firms of different sizes and productivity levels in the same industry. The market price reflects the productivity level of the least productive firm in the industry, which allows the more productive firms to make positive profits and operate on a smaller scale than is economically optimal. According to Heckscher (1924), firm heterogeneity

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14 See, for example Kilkenny and Thisse 1999 for a survey of theories of location.
15 See, for example, Redding (2010) for a survey of empirical studies of the new economic geography framework.
thus induces monopolistic behavior. These thoughts about firm heterogeneity were further developed by among others, Salter (1960) and Solow (1969), whose vintage models imply that production units with old technologies are hit by rising real wages due to improved productivity in new establishments. This competition from new firms forces old firms to invest in new technologies to stay in business, which results in a continuous growth in productivity at the industry level.

Building on these early theoretical contributions work, Melitz (2003) introduces productivity differences across firms in a general equilibrium model of international trade. Only the firms with a productivity level above an endogenously determined cutoff are able to survive in the market. This productivity threshold tends to increase when the country opens up for two-way trade, implying that trade induces a selection effect that determines which firms are operating in the domestic market. Moreover, only firms with sufficiently high productivity decide to enter the foreign markets, as this entry is associated with some fixed costs. Accordingly, the cost of entering foreign markets results in a second selection effect that determines which firms operate on export markets. Melitz shows that international trade results in aggregate productivity gains at the industry level through these two selection effects. Empirical studies of firms’ export behavior provide ample support for this self-selection hypothesis.

Summarizing the theoretical literature on international trade, most economists of today acknowledge at least three explanations to why firms specialize and produce to meet demand outside the domestic market:

- cost advantages due to superior technology (productivity), rich endowment of geographically trapped production factors and/or agglomeration economies
- exploitation of internal scale economies
- exploitation of temporary monopoly rents originating from innovation activities

The next section discusses the role of knowledge in shaping these regional conditions that stimulate firms’ competitiveness in international markets.

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16 See for example Wagner (2007) or Greenaway and Kneller (2007) for a survey of empirical studies of this topic.
3. Knowledge in the production system

The essential role of knowledge in the production system is to transform ideas into economic activity. Accordingly, knowledge basically enters into the production system through investment in R&D activities and through production of advanced goods and services that requires special labor skills. A fundamental property of a knowledge asset is, however, its propensity to leak. This leakage makes knowledge very different from other production factors.

3.1 Knowledge as an input factor

The proclivity of knowledge to trickle out implies that the original knowledge holder can not keep it as a completely private asset. Thus, knowledge is usually considered to have some elements of a public good, i.e. it is non-rival and, to some extent, non-excludable. These two specific properties of knowledge make it economically different from other input factors. Non-rivalry implies that knowledge can be accumulated without bound on a per capita basis, whereas incomplete excludability implies that knowledge tends to spill over between economic agents. As pointed out by Romer (1990), the non-rivalry of a knowledge input induces non-convexity of the production function:

“What thinking about non-rivalry shows is that these features are inextricably linked to nonconvexities. If a nonrival input has productive value, then output cannot be a constant-returns-to-scale function of all its inputs taken together. The standard replication argument used to justify homogeneity of degree one does not apply because it is not necessary to replicate nonrival inputs.” (Romer, 1990, p. 75)

This issue was previously addressed by Schumpeter (1942), Arrow (1962) and Dasgupta and Stiglitz (1988), among others. Unless knowledge spills over completely, instantaneously and without costs, the use of knowledge as an input in production activities induces increasing returns to scale in these activities. Moreover, firm-specific learning implies dynamic scale economies that encourage concentration of industry output, which results in market structures with monopolistic features (Dasgupta and Stiglitz, 1988).

Romer (1990) and Grossman and Helpman (1991a) argue that firms invest in R&D to achieve monopoly power and earn associated above-normal profits. This argument goes back to Schumpeter’s view that monopoly power may be a prerequisite for innovation as firms that have monopoly power face less
market uncertainty and can more easily appropriate the returns from their R&D investments. However, the propensity of knowledge to leak diminishes the monopoly power of firms that accumulate knowledge through investments in R&D or learning by doing. Arrow (1962) stresses that this appropriability problem distorts private incentives to invest in R&D and reduces the aggregate R&D spending to levels below the socially optimal level. This appropriability problem implies that the market power firms may achieve through investment in R&D is in most cases temporary and in most markets firms are exposed to some competition. In contrast to Schumpeter and Arrow, several researchers stress that it is this competition that promotes R&D efforts and innovation (Tang, 2006; Klette and Kortum, 2004; Aghion et al. 2005; among others).

3.2 The effects of knowledge on firm output

Most firm level investments in R&D do not result in path-breaking innovations. Nevertheless, even minor developments of product attributes may bring some monopoly ascendancy to firms that invest in product development. Tang (2006) concludes that different types of competition are associated with different forms of innovation. Depending on the market structure, firms choose to invest in R&D activities that increase consumers’ willingness to pay for the product and/or the quantity sold. Nonetheless, it seems that R&D investments are largely driven by competition in markets with heterogeneous goods, where firms compete through product characteristics rather than through product price. In such markets, firms differentiate their product from the products of its competitors, thereby insulating themselves from pricing-decisions of other firms. Competition with product attributes rather than product price leads back to the issues of monopolistic competition and product differentiation.

To understand how investments in R&D and product development affect the firm, one has to begin with the demand side. The model of location and firms’ pricing behavior developed by Hotelling (1929) can be used to study monopolistic competition by viewing products as being located in product and characteristic space. In Hotelling's spatial model, products differ in only one dimension (location of the seller) but Lancaster (1966a, 1975,) and others showed that Hotelling’s model could be extended to examine products that differ in many dimensions. Specifically, product differentiation in characteristics space substitutes for the traditional form of spatial differentiation. In the new approach to consumer theory developed by Hicks (1956) Morishima (1959), Becker (1965) and Lancaster (1966a), consumers have preferences over the characteristics of commodities rather than over commodities. As mentioned in Section 2.3, Lancaster proposed that it is
these characteristics that are the arguments of utility functions. Commodities consist of bundles of characteristics and commodities containing the same set of characteristics that constitute a product group. The classification of commodities into (weakly or strongly) separable subsets implies that the marginal rate of substitution between two varieties in that subset is independent of the quantity of all goods outside that subset (Morishima, 1973). Within a commodity group, varieties are, however, differentiated by variations in the proportions and combinations of characteristics. According to Lancaster, varieties in the same product group have different proportions of characteristics but none has a larger amount of every attribute that is horizontally differentiated. If a variety has a larger amount of every characteristic than other varieties in the same product group, this variety is regarded as qualitatively superior to other varieties in the commodity group and is differentiated from other varieties in a vertical dimension. Differences in proportions and combinations of characteristics imply that varieties within a product group are imperfect substitutes to each other. The co-existence of many differentiated varieties in the same commodity group reflects either consumer’s “love for variety”, or heterogeneity in consumers’ perceptions of the ideal variety. In the analytical framework of Lancaster (1975; 1980), a consumer maximizes utility by consuming as much of her most preferred variety or most preferred combination of varieties that her budget constraint allows. Dixit and Stiglitz (1977), on the other hand, formulate a CES utility function, where utility is maximized through consumption of as many differentiated varieties as possible given the individual’s budget.

Heterogeneity in consumer preferences allows firms to differentiate their products such that each firm faces a separate downward sloping demand curve. These demand properties provide a possibility for firms to charge a price mark-up over marginal costs i.e. the firm enjoys monopolistic ascendancy on its market. A sufficient condition for such market power is that customers subjectively perceive product varieties as differentiated from each other, although varieties may be very similar from an objective perspective. Hence, the product attributes that differentiate varieties from one another include brand names, product design along with technological characteristics etc. It is generally recognized that product differentiation induces a fixed production cost associated with product innovation and which makes mark-up pricing a necessity for non-negative profits. As a result of investments in product development, products are physically similar but economically differentiated in the sense that buyers perceive them as imperfect substitutes. Provided that the number of suppliers in the commodity group is sufficiently large, so that each firm takes the behavior of the other firms as given and that there are free entry and exit of firms,
product differentiation is consistent with a competitive market equilibrium of zero-profit, i.e. a monopolistically competitive market.

The effect of R&D investments on firm performance also depends on the type of innovation that these investments bring. Following the analytical context of Lancaster (1966a; 1975), the development of a new variety in a product group defined by a given set of characteristics can be regarded as an incremental innovation, as long as the new variety does not include a new attribute or is qualitatively superior to all other existing varieties in the product group. Hence, an incremental innovation brings about a modest novelty in product characteristics, which implies that the aggregate budget share allocated to the product group is likely to remain constant. In contrast to an incremental innovation, a radical innovation refers either to the combination of new characteristics, i.e. the combination of two or more characteristics that has not been combined before, or a combination of characteristics that results in a product quality that is superior to the quality of all other varieties in the market, i.e. a shift in the technological edge of the product group. Furthermore, a radical innovation can refer to a situation of technological substitution, which occurs when new production technologies reduce the price of producing a specific quality level such, that this product quality will replace varieties of lower quality in the product group (Lancaster, 1966b; Grossman and Helpman, 1991b). In comparison with an incremental innovation, a radical innovation is expected to have a stronger impact on the aggregate quantity demanded, as new or improved product attributes or significantly reduced product prices may attract new customers or increase the budget share that each individual devotes to the product group. Hence, a radical innovation is expected to bring a greater market influence to the firm than does an incremental innovation.

Empirical studies on the relationship between knowledge and R&D investments and firm performance show results that are mixed and inconclusive. One of the most robust relationships is that between patents and R&D at the firm level, where evidence is found in studies using cross-sectional as well as longitudinal data (Kortum, 2008). Cross-section analyses also present robust evidences of a positive relationship between firm-level R&D spending and firm-level productivity (Griliches, 1979; 1995, Griliches and Mairesse 1984; Klette and Kortum, 2004). In studies on longitudinal data, however, productivity growth is not found to be strongly related to firm R&D (Klette and Kortum, 2004). Of stronger relevance to the discussion of firms’ aspiration for monopoly profits pursued above, are empirical examinations of the link between R&D investment and firm profitability. Eklund and Wiberg (2007) find a positive relationship between firms’ R&D investments and persistent above normal profits. Empirical results presented
by Johansson and Lööf (2008) indicate a positive effect of investments in R&D and knowledge labor on firms’ profitability which is stronger than the effect of these variables on firms’ labor productivity. These findings suggest that R&D investment bring about some market power to knowledge-intensive firms.

4. Spatial implications of knowledge in the production system

As stated in the beginning of the previous section, knowledge tends to diffuse with or without the approval of the owner of the knowledge asset. This leakage implies that knowledge is partly a public resource. Still, knowledge is not freely available for everyone without cost. Indeed, knowledge formation and accumulation are associated with significant transaction costs, which appear sensitive to geographical distance. The spatial implication of knowledge in the production system is discussed in this section.

4.1 The nature of knowledge flows

There are basically two channels through which knowledge is diffused: interaction of humans and exchange of goods. When interacting with each other, humans clearly share ideas. Beside the exchange of ideas in formal and informal meetings, a number of recent studies emphasize the role of labor mobility for knowledge diffusion (Moen, 2000; Breschi and Lissoni, 2003; Agrawal, Cockburn and McHale, 2006; Thulin (2009), among others). When selling their products, firms to a various degree, reveal the ideas and technologies embodied in their goods.

Following Johansson (2004), knowledge flows can be divided into transaction-based knowledge flows and knowledge spillovers, where the former refers to intentional knowledge transfers that are accomplished through business agreements (for example engineering consulting services, or R&D cooperation) and the latter refers to unintentional knowledge diffusion due to labor mobility, product imitation etc. Hence, unintentional knowledge transfers can be mediated by market mechanisms (for example, on the labor market) or take the form of a pure externality, which is the case when products and technologies are copied and imitated. These different types of knowledge flows are illustrated in figure 1.1:
Moreover, the magnitude of knowledge spillovers depends on the type of knowledge. Following Grossman and Helpman (1991a), there are basically two types of knowledge that are generated by R&D. First, there is technical knowledge concerning specific products or production processes. Second, there is a more general type of knowledge that has a wider applicability to the society as a whole, which is closely associated to scientific knowledge and may be labeled as applied science (Schmookler, 1966). Specific knowledge can, at least partially, be protected by patents whereas general knowledge is non-excludable.

Furthermore, the intentional diffusion or unintentional leakage of knowledge from R&D activities depends on the tractability with which it can be described and codified. Polanyi (1967) distinguished between knowledge that could easily be codified and diffused and knowledge that could only with difficulty be transformed into information. This latter type of knowledge is so-called tacit knowledge, which is highly contextual and complex and therefore mainly embedded in people. Andersson and Beckmann (2009) stress the distinction between knowledge and information and argue that information is a building block in knowledge formation. Knowledge is, at the same time, a necessary tool for making appropriate use of information. The magnitude of knowledge spillovers, through interpersonal contacts or exchange of goods, is therefore strongly related to the complexity of the specific technology or idea or the complexity of the product in which this knowledge asset is embodied. Moreover, the importance of knowledge for understanding and using information implies that the propensity to absorb external knowledge depends on the skills and competencies of the individuals that in various ways and contexts are
exposed to knowledge spillovers. Indeed, for pieces of information to be useful in any context, the receiver must grasp the meaning of it. The importance of this ‘absorptive capacity’ for knowledge transmissions has been confirmed in empirical studies by Cohen and Levintahl (1989, 1990), among others.

4.2 The geography of knowledge flows

Another factor that affects the amount of transaction-based knowledge transfers as well as the magnitude of knowledge spillovers is geographical space. Geography affects the diffusion of knowledge through its effect on personal contacts. The diffusion of complex knowledge, which is largely tacit, is particularly dependent on personal face-to-face communication. Such face-to-face contacts are hindered by geographical distance. Interpersonal meetings are sensitive to geographical distance as the transaction cost and alternative cost of meetings increases with physical distance as well as time distances. Hence, the cost of acquiring knowledge through market-based transactions is often larger if the seller and buyer are located far from each other. There is also a large body of literature in the field of regional economic growth that emphasizes the importance of geographical proximity for knowledge spillover to be significant. Within this field of literature, Glaeser, Kallal, Scheinkman and Schleifer (1992) distinguish between three different lines of theories of regional economic growth: (i) Marshall-Arrow-Romer (MAR), (ii) Porter and (iii) Jacobs.

The MAR theory is a combination of the work by Marshall (1890), Arrow (1962) and Romer (1986), which all suggest that industries concentrate in certain areas because of the advantage of a pooled local labor market. Geographic clusters of firms within the same industry results in a concentration of workers with particular skills. A pooled local labor market reduces the firms’ search cost when recruiting new employees, as well as the search cost of the individual worker that is looking for a new employer. In such clusters, knowledge easily spills over between firms. The MAR theory emphasizes the importance of specialized skill and geographical proximity since it stresses that knowledge mainly spills over between firms in the same industry within a limited geographical area. These knowledge externalities are, to a large extent, mediated by market mechanisms and results in localization economies. However, Arrow (1962) argues that the inability of firms to internalize the benefit of innovation efforts will result in lower investments in R&D than is socially optimal. Subsequently, the MAR theory claims that the presence of many firms and the subsequent competition among them hamper long-term regional economic growth.
Porter (1990) presents another theoretical approach to regional economic development. Local competition stimulates firms to develop new ideas and improve existing technologies, etc. Geographic concentration is important since it facilitates the interaction of people and exchange of ideas, which stimulate innovation and technological progress. In accordance with MAR, Porter suggests that the most significant flows of knowledge take place between firms within the same industry. Hence, Porter also recognizes the importance of localization economies and points out local competition and local specialization as key factors for economic growth.

The third view on regional economic growth is the theory by Jacobs (1969), who suggests that innovation and economic growth is larger in regions where production is characterized by versatility and manifoldness. This kind of dynamism and flexibility is more pronounced in large cities or metropolitan regions because the production structure in these regions is more diversified. Moreover, the demand is also more diversified in cities, which allows for more diversity in the manufacturing sector, even in the presence of internal scale economies. Jacobs argues further that knowledge spillovers are more prevalent in cities since these are environments where people interact to a much greater extent than in other types of settlements. Knowledge transfers are, at the same time, enhanced by the industrial diversity in metropolitan areas because of the possibility of cross-fertilization of ideas. Hence, the diversity and regional size that results from urbanization are important factors for economic growth, according to Jacobs.

Knowledge externalities have been the target of extensive empirical investigation and similar to theoretical work in this field, the empirical literature can also be divided into three categories. First, there are studies that emphasize the role of technological proximity for knowledge spillovers to be significant and suggest that these spillovers occur mainly in supplier-customer linkages (see, for example, Jaffe 1986). Another target for empirical analyses is the role of geographical proximity for knowledge spillovers to take place. A large number of studies indicate that knowledge spillovers are bounded in geographical space (Jaffe, 1989; Anselin, Varga and Acs, 1997, among others). The third perspective of knowledge spillovers in the empirical literature is the international dimension of spillovers. These studies mainly focus on two channels for knowledge spillovers across borders: international trade in goods and intermediates and direct foreign investment. A large number of studies have confirmed the hypothesis that the exchange of goods and intermediates also contains the exchange of technologies and there are ample empirical evidences of the importance of multinational firms as disseminators of technologies across borders.
Knowledge flows within the networks of multinational company groups are likely to be less dependent on geographical proximity as such knowledge transfers, to a large extent, are spread through well established intra-firm linkages. Knowledge flows from multinational affiliates to domestic firms are, on the other hand, likely to be more distance sensitive. Empirical evidences of significant knowledge spillovers from MNE to domestic firms are mixed and inconclusive.\(^{17}\)

Summarizing the implications of knowledge in the production system, it is clear that the intentional or unintentional diffusion of knowledge and information between firms create external scale economies. Consequently, the propensity of knowledge to leak reduces the market power of the firm that initially makes the investment in a knowledge asset and external scale economies may partly offset the internal scale economies that such investments induce. This aspect of knowledge stimulates the growth of the number of firms in an industry as well as the co-location of firms within the industry, rather than the concentration of industry output to few firms. Moreover, intentional as well as unintentional diffusion of knowledge is positively related to geographical proximity. This implies that knowledge-intensive activities tend to be geographically concentrated. Moreover, the agglomeration of knowledge-intensive firms induces a pooling of labor markets in such a way that highly educated labor tend to concentrate in large urban regions. The spatial structure of knowledge-intensive production and the associated geographical distribution of knowledge-intensive workers in the economy are therefore structural patterns that change very slowly (Andersson 1985, Johansson 1993). This notion is, in fact, more than 100 years old as Marshall, already in 1890, stated that externalities generate lock-in effects:

> "When an industry has thus chosen a location for itself, it is likely to stay there long: so great are the advantages which people following the same skilled trade get from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas." (Marshall, 1920 (8th edition, 1st edition published in 1890), p. 225)\(^{18}\)

\(^{17}\) See Keller (2009) for a survey of recent empirical literature in this field.
These arguments suggest that the mobility of knowledge labor is relatively low even between regions within nations. These spatial features of knowledge are discussed further in the next section.

5. Internal geography and external trade

Theoretical models of regions in the international trading system usually consider regions of a spatial scale that is larger than that of nations. Theoretical models considering smaller regions within countries are most often variants of the economic geography framework presented by Krugman (1991) and focus on the influences of trade liberalization on the spatial distribution of production within countries and regional patterns of specialization. Hence, these models focus on the effects of external trade on the internal geography of production and predict a negative relationship between trade openness and urban concentration and a positive relationship between openness to trade and regional specialization (Krugman and Livas, 1992; Fujita, Krugman and Venables, 1999; Behrens et al. 2003). Empirical investigations of these issues bring no convincing evidence of a negative impact of trade liberalization on urban concentration (Ades and Glaeser, 1995; Nitsch, 2006). However, empirical findings support the hypothesis that trade liberalization stimulates regional specialization (Falcioğlu and Akgungör, 2008; Fainstain, 2005; Hanson, 1998). The empirical literature in this field indicates that increased trade and economic integration lead to economic convergence across countries rather than convergence across regions within countries (Behrens et al. 2003). These findings conform well to the reasoning by Davis and Weinstein (1996; 1999) who argue that the core-periphery model of economic geography is more valid in explaining inter-regional patterns of specialization within countries than patterns of specialization and trade across countries. The conventional contrast between international and regional economics, namely, the greater degree of factor mobility across regions within countries than across countries, raises the salience of this issue.

Still, one may argue that the economics of agglomeration that emerge from the interaction among scale economies, factor mobility and transport cost cast geographical patterns of production that result in a very low interregional mobility of some production factors. As discussed in previous sections, knowledge, embodied in highly educated labor, is essentially mobile. Nevertheless, its spatial distribution is highly persistent and invariant over time. One reason is that the regional characteristics attracting human capital (quality of life factors and local labor market attributes) are slowly changing. Another reason is that knowledge workers tend to locate in
regions with already high average levels of education in the labor force since the economic specialization of the regions results in a larger demand for educated workers (Berry and Glaeser 2005). These knowledge assets are (to some extent) used in product-related developments that result in product differentiation in the characteristics space, and this differentiation allows firms to profitably agglomerate in geographic space (Kilkenny, 1998). The accumulative nature of these agglomeration economies implies that location-specific competitive advantages develop and grow to strong structural patterns that require significant external shocks to be altered. Johansson and Wigren (1996) use the term ‘production milieu’ to denote slowly changing spatially sticky features of a region that influence production and specialization opportunities. As already argued, this feature of agglomeration economies is largely relevant for the spatial distribution of knowledge-based activities and subsequent patterns of specialization and trade.

During the 1990s, a large body of theoretical and empirical work emphasized the role of private knowledge investments for technological progress, both at the level of the firm and in the economy at large. A number of theoretical and empirical studies at the micro as well as the macro level of economies also confirm the importance of innovation and R&D for international competitiveness and export performance. Several macro level studies conclude that technological factors are important for countries’ trade specialization (Fagerberg, 1988; Greenlagh, 1990; Gustavsson et al. 1999). Moreover, Grossman and Helpman (1991a), Fagerberg (1994) and Braunerhjelm and Thulin, (2008) show that R&D investments create comparative advantages in high-tech sectors and increase the share of high-tech goods in aggregate export. Regional analyses of R&D and export performance have shown that regional R&D activities stimulate regional export specialization in high-tech goods (Breschi et. al; 1999; Gräsjö, 2006) and increase firms’ export market participation, (Andersson and Johansson, 2008). Micro-level studies present evidences of a positive effect of firm-level R&D investments and firms’ export market participation, as well as their export intensity (Wakelin, 1998; Sterlacchini, 1999; 2001; Bleaney et al. 2002; Barrios et al. 2003; among others).

Based on a data set containing all Swedish firms for the period 1997 – 2004, the studies collected in this dissertation examine how the internal geography of knowledge affects regional export performance and the structure of export flows. Before summarizing the main contributions of these individual studies, this section presents the firm-level export data base and some descriptive statistics of the main variables of interest in this thesis.
5.1 The data

The analysis of regional export flows in this thesis is based on a firm-level data set containing all Swedish firms for the period 1997 – 2004, assembled by Statistics Sweden. The data give information about the location of the firm at the level of municipalities (local government area), which divides Sweden into about 290 localities, depending on which years are considered. The firm-level data are aggregated to the municipality level, which is the smallest spatial unit of the regional analyses in subsequent chapters. Still, these analyses recognize that patterns of spatial interaction rarely follow administrative boundaries. When analyzing knowledge-based activities and associated spillover effects, the geographical patterns of interaction must be considered more carefully. In analyses of spatial interaction, 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 characterized by being a regional labor market, which normally includes several municipalities that are integrated by commuting patterns. Moreover, commuting and all other forms of spatial face-to-face interaction give rise to revenues and costs. The size and spatial pattern of these revenues and costs of interaction determine the geographical boundary of each FUR. For certain activities, such as knowledge exchange, the net returns to spatial interaction are largely dependent on travel-time distances. From the perspective of a FUR there are basically two categories of interaction: travel within the region and travel across regions. Generally, the cost of spatial interaction is significantly higher for interaction across regions than for interaction within a functional urban region. In order to account for the importance of functional urban regions in shaping the geography of human interactions, the empirical analyses in this thesis make use of a travel-time distance matrix between all municipalities in Sweden and apply different time sensitivity parameters for intra-regional and inter-regional interaction when modeling spatial dependencies.

The firm-level data also contain information about export value and export volume for each firm at the 8-digit level of product classification according to the combined nomenclature (CN) and to each destination country. In the four subsequent chapters of this dissertation, each 8-digit product code defines a product group and each firm-level observation in each 8-digit product group is regarded as a unique product variety. Each firm is thus assumed to produce a distinct product variety. Accordingly, each product group contains as many product varieties as the number of firms with positive exports in that product group. The number of ‘firm-product-group-specific’ observations in the export data thus defines the number of product
varieties exported from each municipality. Moreover, firms are classified in industries according to the economic activity that employs the majority of their employees. These industry codes follow the NACE classification system of economic activities and are used to categorize firms into broader economic sectors. Besides export activities, the data base includes a large number of variables reflecting firm characteristics such as number of employees, value added, ownership structure, employees’ educational level etc. Some of these variables have been used to construct regional variables reflecting, for example, multinational firms’ share of regional export or share of regional labor force with higher education etc.

5.2 The geographical distribution of labor, knowledge and export activities in Sweden

This section describes the spatial distribution of employment and export activities in Sweden. Sweden is a sparsely populated country with three metropolitan regions located in the southern part: Stockholm, Göteborg and Malmö. As displayed in Table 1.1, these three largest functional urban regions host almost half of Sweden’s population and a proportional share of the country’s total employment. The number of firms in these local labor market regions is approximately proportional to the size of the population and employment, whereas the regions’ share of the country’s skilled labor force is significantly larger than their share of the total population. As discussed previously, the figures in Table 1.1 reveal that the knowledge labor is strongly concentrated to these urban regions, with a strong predominance of the Stockholm region that hosts 54 % of the labor force with higher education (that is workers with at least three years of university education). Following the localization pattern of the country’s educated labor force, the R&D activities undertaken in firms and academic departments in Sweden are also strongly concentrated to the three metropolitan regions. Of the country’s total R&D efforts 75 – 80 % is carried out in the three metropolitan regions (Gråsjö, 2006; Johansson and Lööf, 2010).
Table 1.1 Concentration of population and economic activity to the three metropolitan regions in Sweden in 2004

<table>
<thead>
<tr>
<th></th>
<th>Share of total population (%)</th>
<th>Share of total employment (%)</th>
<th>Share of total amount of firms (%)</th>
<th>Share of total labor force with higher education (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>24.7</td>
<td>26.7</td>
<td>26.9</td>
<td>54.0</td>
</tr>
<tr>
<td>Göteborg</td>
<td>10.4</td>
<td>10.8</td>
<td>9.9</td>
<td>12.6</td>
</tr>
<tr>
<td>Malmö</td>
<td>11.0</td>
<td>10.2</td>
<td>10.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Total for metropolitan regions</td>
<td>46.1</td>
<td>47.7</td>
<td>47.6</td>
<td>76.1</td>
</tr>
</tbody>
</table>

Source: Aggregation from firm-level statistics, based on Företagsstatistik (SCB) and RAMS (SCB).

The maps in Figure 1.2 below picture employment and knowledge labor in the 290 municipalities in Sweden for the year 2004. The maps display three categories of municipalities the bottom quartile (white) the second and third quartiles (grey) and the top quartile (black). The left map shows that 75% of all Swedish municipalities employ fewer than 7000 persons. In fact, the size of employment in the median municipality only amounts to about 3000 persons. Still, the largest municipality (Stockholm) hosts more than 500 000 employed persons. The right hand map depicts the average level of education in Swedish municipalities. In the top quartile of municipalities, 9% of the employed labor force has at least three years of university education, whereas the highly educated workers make up less than 4% of the labor in the bottom quartile of municipalities. In the average municipality, 6.6% of the employed labor force has a higher education and the median municipality is below average with only about 5% highly educated workers in its employment. The municipalities in the top quartile that are located outside the urban regions of Stockholm, Göteborg and Malmö are in most cases center municipalities in their respective region. They are also most often the municipalities that host a university or college located outside the metropolitan regions.
Turning the interest to export activities, Table 1.2 shows the concentration of Sweden’s total export value, number of exporting firms and number of exported product varieties to the three largest functional urban regions in Sweden. Looking at the sum of these three regions’ share of export value, exporting firms and export products (the bottom row of Table 1.2) it seems as if the geographical distribution of export activities follows the distribution of employment. However, there are substantial differences between these three urban regions. The figures indicate that regional production is more export oriented in Göteborg and Malmö than in Stockholm as the export value, number of exporting firms and number of exported varieties has a stronger concentration to Göteborg and Malmö (except for the export value) than the total national employment.
Table 1.2 Concentration of export activities to the metropolitan regions in Sweden in 2004

<table>
<thead>
<tr>
<th></th>
<th>Share of total employment (%)</th>
<th>Share of total Export value (%)</th>
<th>Share of total amount of exporting firms (%)</th>
<th>Share of total amount of exported product varieties (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>26.7</td>
<td>29.4</td>
<td>28.8</td>
<td>21.7</td>
</tr>
<tr>
<td>Göteborg</td>
<td>10.8</td>
<td>17.3</td>
<td>13.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Malmö</td>
<td>9.8</td>
<td>7.6</td>
<td>11.6</td>
<td>13.3</td>
</tr>
<tr>
<td>Total for metropolitan regions</td>
<td>58.2</td>
<td>54.3</td>
<td>54.1</td>
<td>46.7</td>
</tr>
</tbody>
</table>

Source: Aggregation from firm-level statistics, based on Företagsstatistiken (SCB) and Handelsstatistiken (SCB).

The figures in Table 1.2 call for a more detailed examination of the spatial distribution of export activities in Sweden. Figure 1.3 displays three maps of export activities of Swedish municipalities in terms of a) total export value b) number of exporting firms and c) number of exported product varieties. Again, the municipalities are divided into three categories: the bottom quartile (white) the second and third quartile (grey) and the top quartile (black).

Kilkenny and Thisse (1999) and Klaesson (2002) (among others) stress that transportation infrastructure has a major impact on the spatial distribution of economic activity, with a particular tendency of concentration at the main nodes/markets in the spatial network. Those readers who are familiar with the road network in Sweden can, with the help of Figure 1.3 conclude that this is certainly the case for the spatial distribution of export activities in Sweden. The maps indicate that there is a large variability in export performance of different municipalities within functional regions. There appears to be a fairly strong correlation between the total export value and the number exported product varieties, whereas the municipalities with a large share of educated workers belong to the top quartile in terms of number of exporting firms rather than export value.
Figure 1.3 illustrates that there is no obvious answer to the question of how the location of knowledge labor affects the export performance of municipalities. The next section summarizes the results from the empirical investigations of this issue.
6. Outline of the study and summary of main findings

This thesis contains five chapters, including this introductory chapter. The second chapter has the title *R&D Accessibility and Regional Export Diversity*, and presents a study of how the accessibility to R&D activities in universities and firms influence the diversity of products, firms and destinations in the export flows from municipalities. A theoretical model with fixed R&D cost predicts that spatial knowledge flows generate external economies of scale in R&D activities. These spatial externalities are expected to increase the innovative capacity of firms in a location-specific way. According to this model, the effects of R&D on export performance are reflected by the diversity in export flows rather than by the size of export volumes. The empirical analysis focuses on three different indicators of export diversity: the number of exported varieties, the number of exporting firms and the number of export destinations. The hypothesis is that the accessibility of a location to R&D resources in firms and university departments enhances the export diversity in municipalities. This hypothesis is tested in a spatial cross-regressive model. Since knowledge cannot be regarded as completely trapped in space, the empirical analysis includes two measures of R&D accessibility: intra-regional and inter-regional. With these specifications, the study contributes to existing empirical research on regional specialization and trade in several ways. In contrast to most other studies on regional production and trade, which are normally based upon a geographical division in administrative regions, this analysis considers functional regions for which the geographical borders are determined by actual spatial patterns of interaction. Moreover, this study applies an accessibility approach in modeling geographical dependencies within and between functional regions. The empirical results indicate that the three indicators of a municipality’s export diversity are positively affected by the intra-regional accessibility to company R&D for commodity groups that have a relatively high R&D-intensity in production. A municipality’s accessibility to company R&D has significant positive effects on the number of export varieties and the number of export destinations also in less R&D-intensive industries. In the case of university R&D, the impact of intra-regional accessibility is weaker. 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 most commodity groups. These empirical findings show that knowledge spillover from R&D exercises an influence over a larger spatial scale than has been indicated in several other spill-over studies (Jaffe, 1989, Jaffe, et al. 1993, Gråsjö, 2006,
among others). The outcome of this empirical analysis shows that when knowledge is translated from a blueprint to large-scale production for export markets, geographical proximity is less important. Still, a distance decay remains, in particular, for the most technologically advanced types of goods. The study’s extension to include both intra-regional and inter-regional linkages for knowledge diffusion enriches our understanding of how knowledge networks appear and how such networks influence the spatial patterns of production and export. These are important insights for the design of innovation policy and national and regional innovation strategies.

Chapter 3, *R&D Accessibility and Comparative Advantages in Quality Differentiated Goods*, analyzes how human capital and R&D accessibility influence spatial export specialization along the range of product quality. This study contributes to previous research on specialization and trade in quality differentiated goods by addressing the influence of spatial knowledge flows on the observed patterns of spatial specialization along the product quality spectrum. To my knowledge, there are no previous studies of the geographical distribution of production and export of quality differentiated goods within countries. Previous empirical work on trade in quality differentiated goods are conducted at the level of nations, using cross-country trade data. Another novelty of this study is the use of firm-level data rather than data on aggregate product groups in the assessment of product quality. The empirical analysis is based on a theoretical model of endogenous quality choice and derives locational comparative advantages from the presence of external knowledge flows from R&D activities. The potential of such knowledge transfers is modeled by accessibility variables, which represent the potential of knowledge spillover from R&D activities, distributed across space. The impact of R&D accessibility on each municipality’s revealed comparative advantages in production of high quality goods are subsequently examined in a regression analysis that includes variations across municipalities and across industries. The econometric estimations show significant positive effects of knowledge and R&D accessibility on the revealed comparative advantages of municipalities in the production of high quality goods. The empirical analysis also provides evidence of technology spillovers from abroad, generated via the presence of multinational firms. The presence of multinationals in a municipality and sector increases the spatial specialization in high-quality product segments in that sector. These results are robust over four different specifications of above-average product qualities. While confirming some results from cross-country studies on vertical specialization, this study also identifies spatial knowledge flows as an important factor in explaining spatial patterns of specialization and trade in quality differentiated goods within a country. These results indicate that the design of national and regional policies
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promoting international competitiveness must consider linkages that diffuse technological knowledge over space and across sectors, since these linkages appear to be crucial for quality competitiveness of firms, regions and nations.

The fourth chapter, Scale and Scope - Human capital and the structure of regional export flows, presents an empirical analysis of how the internal geography of human capital in a country shapes the trade flows to foreign markets from its different locations. Focusing on supply-side effects on export flows, this study examines how export flows differ between municipalities that are differently endowed with human capital. With the objective to analyze this issue, the study contributes to the literature in two respects. First, by focusing on human capital, it presents empirical evidence suggesting that the role of locational supply-side characteristics is crucial for the understanding of the internal geography of a country’s aggregate exports. Second, the paper contributes to the literature on how intensive and extensive margins in trade flows adjust to spatial variations in supply-side factors. The development of each export product variety is assumed to be an innovation activity, which requires human capital inputs. In view of this, the core hypothesis is that cross-regional variations in endowments of human capital influence the extensive margin (number of export products) rather than the intensive margin (average export value per product). The hypothesis is tested in a cross-regional regression model, applied to aggregate and within-industry export flows from Swedish municipalities. The empirical results support the theoretical prediction that local concentration of human capital increases the extensive margin of export flows from such locations. To the extent that the regional human capital endowment affects the intensive margin, the effect is a higher average price per export product variety. These findings support the results of the diversity analysis presented in Chapter 2 as they indicate that places that are well endowed with human capital tend to export more varieties rather than larger volumes. The results are also in line with the outcome of the analysis of quality specialization in Chapter 3, since they suggest that locations that are abundant in human capital export goods with a relatively high unit value. Besides providing support in favor of the theoretical conjecture that product differentiation requires knowledge input, the outcome of this analysis suggests that the ability of industries to differentiate their products and achieve the associated competitive advantages is strongly related to the accessibility to human capital in other industries in their own region. This result suggests that long-term competitiveness in export markets for firms located in high-wage countries are strongly dependent on regional availability of labor with university education. The policy implication is straight forward: promoting
regional competitiveness must involve investments in universities and colleges providing higher education to the region’s labor force.

The importance of location-specific factors for firms’ participation in foreign markets is further examined in the final chapter in this thesis: *Market experiences and export decisions in heterogeneous firms*. This empirical analysis focuses on the impact of firm characteristics, firms’ export experiences and location-specific variables on export decisions in Swedish manufacturing firms. Three choices of export market participation are considered: permanent export, occasional export and no export. The paper also analyzes firms’ choice of expanding export activities by introducing additional export products or establishing new geographical export links. The study thereby contributes to the existing literature on firms’ export behavior by examining factors influencing the decision not only to participate in export markets but also the decision to expand export activities to comprise new products and/or new geographical markets. Results from estimations of a multinomial logit model indicate that firm-level variables such as size, human capital intensity and labor productivity increase the probability of a firm being a permanent rather than an occasional exporter or a non-exporter. Moreover, the empirical results reveal that firms that are only occasionally present on export markets have more characteristics in common with non-exporting firms than with permanent exporters. Still, the results indicate that firms located in places with a high concentration of other firms exporting commodities in the same product group have a higher probability of participating in export markets. These results suggest that there are within-industry agglomeration economies that influence the export decision of the individual firm, which may originate from knowledge and information externalities. Moreover, the empirical results also show that firms’ export experiences in previous periods matter. Past experiences from export augment the probability that a firm becomes a permanent exporter in a subsequent period. Hence, it is clearly meaningful to distinguish between permanent and occasional exporters when explaining firms’ export performance. The analysis of export market expansion suggests that firms with high human capital intensity and experiences from exporting several products to several markets are more likely to introduce a new product variety on export markets. The probability of expanding exports to new geographical markets increases with firm-level labor productivity and with export experiences from multiple markets in previous periods. The general conclusion from this analysis is that export promoting policies are likely to be most efficient when targeting firms that have some previous experience from export markets. Moreover, when carried out in regions with many exporting firms, publicly financed export initiatives may stimulate export market participation in neighboring firms.
In summary, the empirical results of this thesis convey the message that regional accessibility to knowledge, embodied in highly educated labor and/or developed through R&D activities, plays a fundamental role in shaping the content and structure of regional export flows. More specifically, the present empirical observations suggest that the regional endowment of knowledge stimulates the size of the export base in terms of exporting firms and number of product varieties. The recurring significance of the accessibility variables in explaining spatial export patterns show that the knowledge endowment of a region must be defined in such ways that it captures sources of potential knowledge spillovers from inside as well as outside its own regional boundaries. Still, geographical distance has a negative impact on the potential for knowledge to diffuse. These findings show that regional variations in knowledge endowments originate both in the actual spatial distribution of a nation’s knowledge labor across regions and in regional differences in the geographical accessibility to internal and external knowledge labor.
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Chapter 2:
R&D Accessibility and Regional Export Diversity

Sara Johansson and Charlie Karlsson

Abstract

This paper examines the influences of accessibility to R&D on the export diversity in Swedish municipalities. A theoretical model with fixed R&D cost predicts that spatial knowledge flows generate external economies of scale in R&D activities. These spatial externalities are assumed to increase the innovative capacity of firms in a location-specific way. Moreover, the model implies that the effects of R&D on regional export performance are reflected by the diversity in aggregate export flows rather than by the export volumes. The empirical analysis focuses 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 the accessibility to R&D resources in the private business sector and university departments has a positive influence on the diversity of export flows is tested in a spatial cross-regressive model. Since knowledge can not 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 product groups. In the case of university R&D, the empirical results are weaker. Still, 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, R&D, knowledge flows
JEL classification: R11, R12, F12

I. Introduction

It is 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 (Wakelin, 1998; Bernard and Jensen, 1999; Sterlacchini, 1999; 2001; Bleaney and Wakelin, 2002; Barrios, Görg and Strobl, 2003). However, R&D activities are, in general, strongly concentrated to large functional urban regions and a large number of empirical studies indicate that knowledge flows are bounded in geographical space. It is obvious that these two factors play a fundamental role in shaping regional patterns of specialization and comparative advantages (Grossman & Helpman, 1991). The new theory of specialization and trade that has emerged within the so-called “New Economic Geography” framework emphasizes the role of the functional region rather than the nation (Johansson and Karlsson, 2001). Pertinent models assume that the economy of a functional region primarily develops through self-organized interaction processes between economic actors. Nevertheless, most empirical studies of the role of R&D in determining patterns of trade specialization have been conducted at the level of nations (van Hulst, Mulder and Soete, 1991; Amendola, Dosi and Papagni, 1993; Magnier and Toujas-Bernate, 1994; Fagerberg, 1995; Amable and Verspagen, 1995; Amendola, Guerrieri and Padoan, 1998). These studies give evidences of significant links between R&D performance and international competitiveness of industrialized 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. However, there are few empirical studies examining the link between R&D specialization of regions and their patterns of trade and comparative advantages (Sjöholm, 1996; Breschi and Palma, 1999; Gräsjö, 2006; Andersson and Ejermo, 2006), but they indicate robust relationships between the innovative capabilities of regions and their export performance.

The limited number of empirical studies of the possible links between the R&D specialization of regions and their patterns of trade and comparative advantages is per se a motivation for more empirical research. There are, however, also methodological reasons for doing more empirical studies. Earlier studies are normally based upon a geographical division in administrative regions, which usually deviate from functionally defined
regions. Following the recommendations in Andersson and Karlsson (2006), this paper focuses on functional regions, for which the geographical borders are determined by spatial patterns of interaction (Johansson, 1993). In addition, earlier studies have used very crude measures to represent the role of geographical proximity in knowledge exchange and diffusion.

The purpose of this paper is to analyze how R&D accessibility affects the export performance of local urban areas (municipalities) in Sweden. In contrast to previous studies of regional export performance this empirical analysis emphasizes the role of R&D for regional export diversity. The particular issue of concern is whether a location’s accessibility to university R&D, on the one hand, and company R&D on the other hand, increases the diversity in export flows from that location. Thus, the objective of this empirical study is not to analyze export performance in terms of total value or volume of export flows, but to investigate the export performance of municipalities in terms of the number of exporting firms and number of export product varieties within ten aggregate product groups. This approach relies on the recognition that a significant part of the R&D efforts of firms in Sweden is focused on product innovation (Nyström, 2006) and, as suggested by 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 of R&D activities on regional export performance are likely to be reflected in an expanding export base, i.e. an increasing number of exported product varieties and exporting firms, rather than by growing exported volumes of each product variety.

Furthermore, this paper examines a geographical dimension of regional export diversity measured by the number of destination countries that the export from a municipality reaches. The limited size of national markets generates a natural incentive for firms to export their products to many foreign markets since the returns from R&D often take the form of some temporary monopoly rent. Such rents are likely to be higher when an innovative product variety is introduced on many 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. Accordingly, successful innovation will result in improved competitiveness, either in terms of product characteristics (product innovation) or in terms of product price (process innovation), which results in a more dispersed geographical distribution of a location’s aggregate export flow.

In order to investigate the importance of R&D for regional export diversity three different indicators of diversity are used as dependent variables in a
spatial cross-regressive analysis based on export data for Swedish municipalities in the year 2002. These three diversity indicators are the number of exported product varieties, the number of exporting firms and the number of export destinations. The reason for conducting the empirical analysis on the level of municipalities, which is an administrative geographical region rather than a functional region, is that municipality data contain more variability and gives a larger number of observations. This study emphasizes the role of the functional region as a source of R&D externalities, which affects the innovative capacity of firms in municipalities in a functional region. Since labor and, in particular, knowledge, is not fixed to a specific location, the intra-regional accessibility to R&D is measured on the level of regional labor markets, which can be regarded as functional regions. Furthermore, the influence of the inter-regional knowledge spillovers is taken into account through measurements of accessibility to R&D in all other functional regions in Sweden. Accordingly, for each location we measure the municipality’s accessibility to R&D efforts within their own functional region (intra-regional accessibility) and the accessibility to R&D efforts in all other functional regions (inter-regional accessibility). The R&D efforts are measured by the number of R&D workers in the private business sector and in academic departments.

A theoretical conjecture that knowledge flows are bounded in space has been confirmed in a number of empirical studies. In an analysis of data on patent citations Jaffe, Trajtenberg and Henderson (1993) showed that knowledge flows are strongly localized in geographical space. Their findings suggest that the benefits of knowledge are higher in the region or country where it is generated than in other regions or countries. The effects of geographical distance on knowledge flows was shown even earlier by Jaffe (1989) in an analysis of the relationship between university R&D and patenting activity. In general, firms are more likely to benefit from R&D conducted in universities located in their home states than from other universities. Anselin, Varga and Acs (1997) have analyzed local knowledge flows from university R&D to innovative activities by small high technology firms, using innovation counts for 125 metropolitan regions in the US. They find that knowledge flows from university R&D have a positive and significant impact on regional rates of innovation. They also find that the impacts extend over a range of 120 kilometers from the innovating region, implying that spatial contiguity is important for knowledge flows and that knowledge flows extend beyond the borders of functional regions.

The outline of this paper is as follows: In the next section a spatial model of production with fixed R&D costs is outlined. Section 3 addresses two important empirical issues, namely the definition of functional regions and
the measurement of regional accessibility to R&D. This section also presents the spatial cross-regressive model applied in the econometric estimations. Section 4 presents and discusses the empirical results and the outcomes and implications of this study are summarized in Section 5.

2. Theoretical Framework

Imperfect competition and increasing returns are pervasive features of contemporary industrialized economies. Theoretically, these economic issues are mainly addressed in the literature of industrial organization and in the new trade theory (Dixit and Stilts, 1977; Dixit and Norman, 1980; Lancaster, 1980; Krugman, 1979, 1980; Ethier, 1982; Helpman, 1984, among others). With increasing returns to scale, trade develops because of advantages of specialization among regions, which are very similar to each other in terms of resource endowments. When specialization and trade are driven by economies of scale rather than by factor endowments, the gains from trade take the form of reduced production costs as the scale of output increases and an increased product variety available for consumption due to import. The following subsection outlines a spatial model with increasing returns to scale based on the classical model by Krugman (1980).

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 considered in this model is the cost of conducting R&D. Assuming that labor is the only factor of production in manufacturing, the production of manufacturing goods exhibits increasing returns according to the following formulation:

\[ L_M = L_{R&D} + aQ_M \]  

(2.1)

where \( L_M \) represents the total amount of labor employed by the representative firm in the manufacturing sector, \( L_{R&D} \) represents the fixed amount of R&D personnel in each firm. The parameter \( a \) is a constant reflecting the labor input requirement per unit of manufacturing output and \( Q_M \) is the total output of each manufacturing firm. Consumers are assumed to have preference for variety and each manufacturing firm is assumed to produce a unique product variety that enters symmetrically into consumers’ utility function. The market for a specific product group is then characterized
by monopolistic competition. Each monopolistic producer perceives the elasticity of demand for their own product as equal to $\sigma$, implying that the price mark-up over the marginal costs can be expressed as:

$$ P_i(1-1/\sigma) = aw \quad (\sigma > 1) \quad (2.2) $$

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 labor. Equation (2.2) can be transformed to express the market price as:

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

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

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

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

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

where $Q_M^*$ is the profit-maximizing output level of a manufacturing firm. The equilibrium labor demand of each firm, $L_M^*$, is given by:

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

The above equations show that when each firm produces a single product variety with the same production technology and faces the same input prices, the zero-profit equilibrium imply that all firms have the same size and charge the same market price. With a fixed amount of workers available for the
manufacturing industry in a region, \( \bar{L} \), the number of goods produced in the manufacturing sector, \( n \), is determined by:

\[
\frac{\bar{L}}{L_{M}} = \frac{\bar{L}}{L_{R&D} + a L_{R&D}[(\sigma - 1)/\alpha]} = \frac{\bar{L}}{L_{R&D}\sigma}
\]  

Equation 2.7 implies that the volume of R&D labor needed to develop a product variety determines the number of varieties produced in a region and thus the number of potential varieties exported\(^{18}\). Equation (2.7) also implies that the larger the size of the region, \textit{ceteris paribus}, the larger the number of product varieties produced.

Moreover, Equation 2.7 states that the larger the R&D input in production the less diversified a region will be as the workers available for R&D activities is fixed. However, the result in (2.7) may be extended to include the influence of knowledge externalities, i.e. knowledge spillovers from R&D activities. This extension is made in Equation 2.8, where the parameter \( \varphi \) is assumed to be a function of the accessibility to R&D in other firms as well as in universities, and reflects the productivity of labor employed in R&D activities:

\[
\frac{\bar{L}}{(L_{R&D})^{1/\varphi}\sigma} = \varphi \geq 1
\]  

When \( \varphi > 1 \) there are significant knowledge flows from other firms and university research that reduce the volume of own R&D necessary to develop and produce a product variety. The efficiency of R&D workers increases due to knowledge spillovers, which indicates that there are external economies of scale in innovating activities. Hence, the model outlined in this section suggests that the richer the knowledge milieu of a region the more efficient are the innovative activities and the larger are the number of product varieties produced. The more varieties produced the larger the number of potential export varieties in the region. The geographical aspects of the knowledge flows that produce this theoretical outcome are thoroughly discussed in the next subsection.

\(^{18}\) 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.
2.2 Spatial Knowledge Flows

As recognized by among others, Cheshire and Malecki (2004), a firm’s own R&D 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 and Cohendet, 1999; Kuemmerle, 1999). Another well-known result from the literature is that knowledge tends to flow between economic agents. Accordingly, knowledge is often recognized as, at least partly, a public good since its use by one agent in no way limits its use by other agents. Yet, for certain types of knowledge it is possible to exclude other economic actors from using it commercially by means of patents, trade secrets, etc. However, the fact that knowledge is non-rivalrous and, in principle, also non-excludable when it comes to be used in future R&D projects, does not imply that external knowledge is freely accessible without costs at any point in geographical space. Much knowledge is tacit or sticky in the sense that it is not codified. This is certainly true for new discoveries generated in R&D labs. Such tacit knowledge is mainly exchanged through channels for interpersonal contacts, such as face-to-face communications, meetings, seminars, supervision, on-the-job training, etc, whose frequency and effectiveness decrease with the time distance between the agents involved (Pred, 1966; Feldman, 1994). Thus, the transmission and absorption of technological and scientific knowledge is facilitated by geographical proximity.

The exchange of knowledge takes place in different spatial “knowledge” networks. These networks may, but do not have to 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 multitudinous ways. Since networking on distant links is more costly than on local links, interaction will be more frequent in local and intra-regional networks. This effect can be quite pronounced, since spatial interaction costs may increase in a non-linear manner at certain distances (cf. Johansson and 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 the knowledge bases are, the more probable it is that geographical proximity will play a significant role in facilitating the transmission of such knowledge (Breschi and Palma, 1999). Thus, the cost of knowledge production, i.e. R&D, is inversely related to the richness of the knowledge flows in each region. The richer the knowledge flows in a functional urban region, the lower the fixed R&D costs, which stimulate the development of new product varieties.
The geographical limitations of knowledge flows imply that there is a high probability that different regions will develop their own specialized knowledge base in a path-dependent manner. Moreover, regions that deliberately increase their investments in R&D and/or improve intra-regional transport infrastructure may develop a comparative knowledge advantage vis-à-vis other regions over time. Consequently, we may hypothesize 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 R&D efforts. The model outlined above assumes that each firm produces a single product variety 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, which would result in extended product lines in a few large firms. However, when there are external economies of scale in knowledge-intensive 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). The prediction 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. The core hypothesis to be tested is, accordingly, if there is a positive impact of spatial R&D accessibility on the diversity in municipalities’ export flows. However, before plunging into empirical testing, a discussion of the definition of functional regions and how their geographical interaction can be measured is appropriate.

3. Empirical Methodology

Before testing the hypotheses formulated above, the problem of how to measure spatial accessibility to 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, must be solved. In econometric estimations, two types of spatial dependencies, extensively treated in the literature, may influence the estimation results: spatial interaction of the dependent variable and
spatially dependent error terms (Anselin, 1988; Anselin and Florax, 1995). The first type of spatial dependence (substantive dependence) originates from economic phenomena incorporating spatial interaction, whereas the latter (nuisance dependence) refers to spatial autocorrelation in the error terms generated by spatial dependence in unobserved variables. In the context of regional export, it is appropriate to consider spatial interdependence in the regressand, implying that a spatial lag, which reflects the presence of spatial dependence, must be included among the regressors.

Spatially lagged models can take many forms but, as suggested by Niebuhr (2003) and Andersson and Gråsjö (2006), a spatial cross-regressive model, which includes spatially lagged explanatory variables, is a convenient model specification when spatial interaction costs and/or spatial externalities are assumed to take a non-linear form. According to the theory outlined in the previous section, we suppose that the dependent variable, the number of export varieties/firms/destinations in regions $s (n_s)$, is a function of the amount of R&D conducted in its own region and the amount of R&D knowledge that spills over from surrounding regions as well as from more remote locations at a rate that is decreasing with distance. A natural way of formulating this relationship is:

$$n_s = \alpha + \beta D W_s + \mu_s$$

(3.1)

where $D$ is the R&D conducted in the regional system considered, and $W_s$ is a spatial weight matrix measuring the various directions of spatial dependence between location $s$ and all other locations in the regional system. Hence, this matrix specifies the geographical structure and intensity of spatial interaction. Each element $w_{sr}$ in $W_s$, represents the intensity of interaction between location $s$ and $r$, which can be interpreted as the potential for spatial knowledge spillover from R&D. Niebuhr (2003) suggests that the elements of the spatial weight matrix can be generated by a distance decay function: $w_{sr} = \exp\{-\lambda t_{sr}\}$, where $t_{sr}$ is the travel time distance between location $s$ and $r$ and $\lambda$ is a time sensitivity parameter, assumed to be larger than zero. Andersson and Gråsjö (2006) call attention to this formulation of the spatial lag model as being the result of the inclusion of accessibility variables among the regressors in traditional cross-regional regression models.
3.1 Accessibility Defined

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 characterized by being an integrated regional labor 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. More specifically, the regional division used in this study is mapped from actual commuting patterns, which implies that a FUR is equivalent to an integrated regional labor market\(^{19}\).

A functional region can increase its knowledge endowments by extending and improving its interaction with other regions, thereby amplifying 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 and Wood, 1993; Gassman and von Zedtwitz, 1998 & 1999; Blanc and Serra, 1999; von Zedtwitz and 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 domestic interaction, have large research in universities, etc. The costs of accessing knowledge from other regions are generally lower in large functional urban regions than in smaller functional regions.

From the perspective of a functional urban region there are two relevant types of travel: travel within the functional urban region and travel to all other regions. This implies that for any kind of R&D efforts two relevant measures of geographical proximity can be calculated: intra-regional and inter-regional accessibility. Approximating the amount of R&D conducted in a given location by the number of man-years devoted to R&D activities in the private business sector and in the academic departments, the accessibility of municipality \(s\) (\(s = 1 \ldots n\)) to R&D activities (\(D_s\)) within the own municipality and within the n-1 surrounding municipality can be defined as follows:

\[^{19}\text{For a thorough discussion of the geographical extension of FURs, see the CESIS working paper version of this paper: http://www.infra.kth.se/cesis/cessis/publications/index.htm}\]
where $A_s^D$ is the total accessibility of location $s$ to the R&D in different locations $D_1, D_2, ..., D_n$. $f(c)$ is the distance decay function that reflects how the accessibility value is related to the cost of reaching the R&D activity in the given location. According to Equation 3.2, a municipality’s accessibility is defined as the sum of its internal accessibility to the opportunity $D$ and its accessibility to the same opportunity in all other municipalities in the set $\{1, ..., n\}$. Following Johansson and Klaesson (2001) and Niebuhr (2003) the distance decay function is assumed to take a negative exponential form:

$$f(c) = \exp(-\lambda t_{sr})$$

where $t_{sr}$ is the travel-time distance between region $s$ and $r$ and $\lambda$ is a pre-estimated time-sensitivity parameter, reflecting how the accessibility responds to changes in travel-time distances. Combining Equations (3.2) and (3.3), the accessibility of municipality $s$ to R&D activities is defined in as

$$A_s^D = \sum_{r=1}^{n} D_r \exp(-\lambda t_{sr})$$

Since the time sensitivity parameter differs between travels of different distances (Johansson, Klaesson and Olsson, 2002; 2003), it is relevant to divide a municipality’s total accessibility to any particular opportunity into three parts:

$$A_s^D = A_s^{DL} + A_s^{IR} + A_s^{IR}$$

where, $A_s^{DL}$, $A_s^{IR}$ and $A_s^{IR}$ express local, intra-regional and inter-regional accessibility to R&D respectively. Local accessibility is relevant to unplanned contacts where the time distance is sufficiently low to allow for several contacts per day. Intra-regional accessibility is relevant to travels made on a regular basis, such as commuting but the time distance is too large for several unplanned contacts per day. For inter-regional accessibility, the time distance is too large for commuting. Such contacts are therefore likely to constitute planned activities, such as business meetings, fairs, conferences.

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20 An accessibility measure of the type discussed here should satisfy certain criteria of consistency and meaningfulness. It should be emphasized that the expression in (3.4) satisfies such warranted criteria (Weibull, 1976)
R&D Accessibility and Regional Export Diversity

Furthermore, Johansson, Klaesson and Olsson, (2002) estimate different time sensitivity parameters $\lambda$ for local, intra-regional and inter-regional interaction. Inside a municipality parameter $\lambda_1$ applies, inside the pertinent region parameter $\lambda_2$ applies and for contacts outside the region parameter $\lambda_3$ applies and these parameters differ in size in the following way: $\lambda_2 > \lambda_3 > \lambda_1$, which means that the time friction is greater for intra-regional travels than for inter-regional travels and smallest for short travel time distances within a municipality.

In order to explain the three different accessibility measures one has to start at the local level. The average time distance between zones in municipality $s$, located in the functional region $R$, is denoted by $t_{ss}$ and the size of R&D activities in the same municipality is given by $D_s$, implying that the intra-municipal accessibility to R&D can be expressed by

$$A_{ss} = \exp\left[-\lambda_1 t_{ss}\right]D_s$$  \hspace{1cm} (3.6a)

In municipality $s$ the economic actors have accessibility to R&D activities in all other municipalities that belong to region $R$. By letting $t_{sr}$ denote the time distance between municipality $s$ and $r$ the within-regional accessibility of municipality $s$ can be expressed as

$$A_{sr} = \sum_{r \in R, r \neq s} \exp\left[-\lambda_2 t_{sr}\right]D_r$$  \hspace{1cm} (3.6b)

Economic actors in municipality $s$ also have accessibility to R&D activities in all municipalities outside region $R$. This inter-regional accessibility is specified as:

$$A_{sk} = \sum_{k \notin R} \exp\left[-\lambda_3 t_{sk}\right]D_k$$  \hspace{1cm} (3.6c)

---

21 It is worthwhile noting that the relevant mode of transport may differ between the three accessibilities. However, the data on travel times in this study only includes travels by car. For policy implications, though, it is desirable to include travel times by other transport modes (railway and air).
Equations 3.6a – 3.6c express three categories of accessibility:

(i) Local accessibility \( = A_{sl}^D \)
(ii) Regional accessibility \( = A_{st}^D \)
(iii) Inter-regional accessibility \( = A_{sER}^D \)

However, because knowledge is partly a public good, which is not necessarily fixed to a specific location, the local accessibility to R&D workers alone is of minor importance in this study. Since each municipality forms part of a larger labor market region, characterized by regular commuting, it is more relevant to merge the local and intra-regional accessibilities in Equation 3.6a and 3.6b to one aggregate measure of accessibility to R&D activities within its own functional region that we label intra-regional accessibility:

\[
A_{sIR}^D = A_{sl}^D + A_{st}^D \]  

(3.6d)

Accordingly, this empirical analysis focuses on two measures describing the accessibility conditions for municipality \( s \) regarding R&D activities, namely its intra-regional accessibility, \( A_{sIR}^D \), and its inter-regional accessibility, \( A_{sER}^D \).

### 3.2 Data and model specification

The empirical analysis of the relationships between export diversity and spatial spillovers from R&D is based on firm-level data of Swedish export 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 from each firm of all types of manufacturing products according to the 8-digit level of the combined nomenclature, which are used to define the number of export varieties at the municipality level. The data set also includes the destination of each firm’s export of a particular variety, which has been used to determine the number of destinations for the export from each municipality. The measures of the intra- and inter-regional accessibility to university and company R&D labors are based on travel-time distances between all Swedish municipalities and the average number of full-year working time equivalents devoted to R&D in each municipality over the period 1993 to 1999. Hence, it is assumed that the effects of R&D on export diversity persist over some time.

For the purpose of capturing spatial dependencies, we apply a cross-regressive model where the independent variables of the regression model
are formulated in terms of accessibility according to Equations 3.6a-d. As shown by Andersson and Gräsjö (2006) the inclusion of spatially lagged dependent variables in the form of accessibility variables significantly reduces the incidence of spatially autocorrelation in the residuals. As a consequence, a significant estimated impact of the accessibility variables indicate presence of spatial dependencies, which can be interpreted as an indication of geographical knowledge spillovers. Accordingly, the variable $\text{DW}_s$ in Equation 3.1 is replaced by these accessibility variables ($\text{DW}_s = A_{s IR}^D + A_{s ER}^D$) and the spatial cross-regressive model to be estimated in this analysis is consequently formulated as:

$$n_s = \alpha + \beta_1 A_{s IR}^D + \beta_2 A_{s ER}^D + \beta_3 S_s + \epsilon_s$$  \hspace{1cm} (3.7)

The dependent variable, $n$, denotes regional export diversity (in terms of number of export goods, number of export firms and number of export destinations) in municipality $s$. $\alpha$ is the intercept term, $A_{s IR}^D$ and $A_{s ER}^D$ are the variables reflecting intra- and inter-regional accessibility to R&D respectively. $S$ is the size of municipality $s$, measured by its population, which is used as a control variable and $\epsilon$ is a stochastic error term assumed to have zero mean and constant variance.

Still, 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 multicollinearity between the two types of R&D labor considered in this paper (university respectively company R&D workers). In order to facilitate interpretation of estimated coefficients, the regression model in Equation 3.7 is estimated in two different specifications, one including accessibility to company R&D workers and the other including university R&D workers. Moreover, the knowledge and R&D intensity varies significantly between different types of products, as does the potential for product differentiation. This product heterogeneity with respect to production functions and differentiation opportunities may induce an identification problem since the diversity of a municipality’s export may reflect the industrial structure of the manufacturing sector in the municipality rather than its spatial accessibility to R&D. In order to preclude empirical results generated by spatial variations in industrial structure rather than by spatial variations in R&D accessibility, the cross-regressive model in Equation 3.7 is estimated separately on data for 10 sub-groups of manufactured commodities. The results of these estimations are presented in section 4.
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 are applied: 1) the number of exported product varieties 2) the number of exporting firms and 3) the number of export destinations. The spatial model of production with fixed R&D costs outlined in Section 2 implies that the presence of external knowledge spillovers increases the efficiency of R&D activities. These spillovers translate into larger export base in locations that host a lot of R&D activities and/or have good spatial accessibility to R&D activities in other locations. Assuming that intra- and inter-regional accessibility to R&D reflects the presence of such spillovers, locations with good R&D accessibility are expected to have a more diversified production structure and export than regions with poor accessibility to R&D. Thus, we anticipate a positive relationship between intra-regional and inter-regional R&D accessibility and number of export varieties, number of exporting firms and number of export destinations in the region. The two specifications of the regression model presented in Section 3.3 (the first including company R&D and the second including university R&D) are estimated both on the total export of all types of product varieties and on data on ten sub-groups of commodities.

The first estimations consider the impact of R&D accessibility on the number of exported varieties in each municipality. The results of these regressions are presented in Table 2.1 (company R&D) and 2.2 (university R&D). The estimated results for the aggregate export (the second row in Table 2.1) reveal that the number of products 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 a strong impact on the number of exported product varieties, which supports the basic theoretical assumption of increasing returns to scale in the manufacturing industry. Small municipalities specialize in the production of a smaller range of varieties, whereas large municipalities achieve a more diversified export since more firms are able to produce on the minimum efficient scale. The regressions estimated on specific commodity groups reveal 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 appears more important in diversifying export flows in commodity groups that are R&D-intensive. Telecom and electronic products have the largest estimated coefficient for both intra- and
inter-regional accessibility to company R&D labor, 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 whose export bases increases with the intra-regional R&D accessibility, also experience a positive impact of inter-regional accessibility to R&D labor. For the production of motor vehicles and other transport equipment the inter-regional accessibility to R&D has a significant positive impact on the number of exported varieties in a particular location, whereas the intra-regional R&D accessibility is not significant. In less technological advanced product groups the accessibility to R&D has no significant effect on the number of export varieties produced in a specific location.
Table 2.1 Effects of accessibility to company R&D on the number of export varieties

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

$t$-values in parentheses, * denotes significance at 5%.

The estimates in Table 2.2 show that the intra-regional accessibility to university R&D labor 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 has significant positive influences on the number of export varieties in all commodity groups but agricultural and food products, wood and paper, and textiles.

Table 2.2 Effects of accessibility to university R&D on the number of export varieties

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Intra-regional accessibility to university R&amp;D</th>
<th>Inter-regional accessibility to university R&amp;D</th>
<th>Size</th>
<th>Constant</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All commodities</td>
<td>0.1533 (1.441)</td>
<td>0.4975* (2.958)</td>
<td>0.0076* (5.767)</td>
<td>135.634* (4.296)</td>
<td>0.75</td>
</tr>
<tr>
<td>Agricultural and food products</td>
<td>-0.0006 (-0.005)</td>
<td>0.0238 (1.099)</td>
<td>0.0005* (2.445)</td>
<td>-5.584* (-2.162)</td>
<td>0.72</td>
</tr>
<tr>
<td>Mineral based products</td>
<td>0.0057 (1.256)</td>
<td>0.0174* (2.292)</td>
<td>0.0004* (7.211)</td>
<td>4.055* (2.871)</td>
<td>0.76</td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.0322* (2.020)</td>
<td>0.0832* (3.087)</td>
<td>0.0011* (4.995)</td>
<td>10.915* (2.238)</td>
<td>0.72</td>
</tr>
<tr>
<td>Products of wood and paper</td>
<td>0.0030 (0.409)</td>
<td>0.0146 (1.552)</td>
<td>0.0004* (5.150)</td>
<td>17.852* (7.923)</td>
<td>0.60</td>
</tr>
<tr>
<td>Products of textile, leather, fur</td>
<td>0.0123 (0.458)</td>
<td>0.0506 (1.049)</td>
<td>0.0011* (5.353)</td>
<td>16.033* (2.661)</td>
<td>0.44</td>
</tr>
<tr>
<td>Metal products</td>
<td>0.0076 (0.529)</td>
<td>0.0377* (2.070)</td>
<td>0.0009* (4.501)</td>
<td>23.792* (4.656)</td>
<td>0.63</td>
</tr>
<tr>
<td>Industrial machinery</td>
<td>0.0180 (1.184)</td>
<td>0.0803* (3.022)</td>
<td>0.0010* (4.542)</td>
<td>35.107* (6.504)</td>
<td>0.66</td>
</tr>
<tr>
<td>Motor vehicles and transport</td>
<td>0.0006 (0.259)</td>
<td>0.0125* (2.501)</td>
<td>0.0003* (5.371)</td>
<td>9.286* (6.976)</td>
<td>0.70</td>
</tr>
<tr>
<td>electronics</td>
<td>0.0686* (3.330)</td>
<td>0.1397* (2.235)</td>
<td>0.0010* (4.202)</td>
<td>19.112* (3.076)</td>
<td>0.69</td>
</tr>
<tr>
<td>Furniture, arts and sport articles</td>
<td>0.0056 (0.877)</td>
<td>0.0276* (2.584)</td>
<td>0.0003* (4.245)</td>
<td>13.500* (6.158)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

t-values in parentheses, * denotes significance at 5%.
One reason for the predominant impact of inter-regional knowledge flows over intra-regional flows in the regressions including university R&D is that many Swedish municipalities have very similar intra-regional accessibility to university R&D, whereas the inter-regional accessibility to university R&D contains larger variation. However, an interesting feature is that there are significant inter-regional spillover effects also from company R&D (Table 2.1).

Addressing the issue of export diversity in terms of number of exporting firms, Table 2.3 presents the results of the estimation of the impact of company R&D accessibility 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 prominent for R&D-intensive product groups (telecom and electronics, industrial machinery and chemicals), whereas the number of exporting firms in low-tech product groups does not reveal any significant influences from intra-regional R&D efforts in the private business sector.

An interesting feature is that R&D activities performed in municipalities outside their own functional region do not significantly affect the number of exporting firms in a municipality. Hence, the variation in the number of exporting firms among municipalities is explained only by variations in the accessibility to R&D within its 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 (Table 2.1). This finding suggests that part of the R&D efforts made in the private business sector result in an increased number of export product varieties in other regions, but do not lead to any significant increase in the number of exporting firms. This outcome points to some firm level economies of scope in R&D activities and that knowledge generated by R&D activities in private companies are diffused by intra-firm and intra-industry linkages.
Table 2.3 Effects of accessibility to company R&D on the number of exporting firms

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Intra-regional accessibility to company R&amp;D</th>
<th>Inter-regional accessibility to company R&amp;D</th>
<th>Size</th>
<th>Constant</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All commodities</td>
<td>0.3342*</td>
<td>-0.4894</td>
<td>0.0047*</td>
<td>-43.948*</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>(2.545)</td>
<td>(-1.124)</td>
<td>(11.170)</td>
<td>(-4.015)</td>
<td></td>
</tr>
<tr>
<td>Agricultural and food products</td>
<td>0.0204</td>
<td>-0.0055</td>
<td>0.0003*</td>
<td>-3.133*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(1.910)</td>
<td>(-0.150)</td>
<td>(13.577)</td>
<td>(-4.571)</td>
<td></td>
</tr>
<tr>
<td>Mineral based products</td>
<td>0.0398*</td>
<td>-0.0245</td>
<td>0.0005*</td>
<td>-4.535*</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(2.501)</td>
<td>(-0.475)</td>
<td>(13.532)</td>
<td>(-4.343)</td>
<td></td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.1080*</td>
<td>-0.0231</td>
<td>0.0010*</td>
<td>-10.234</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(2.948)</td>
<td>(-0.187)</td>
<td>(4.611)</td>
<td>(-4.767)</td>
<td></td>
</tr>
<tr>
<td>Products of wood and paper</td>
<td>0.1331*</td>
<td>-0.1895</td>
<td>0.0017*</td>
<td>-19.999*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(2.190)</td>
<td>(-1.033)</td>
<td>(7.960)</td>
<td>(-3.864)</td>
<td></td>
</tr>
<tr>
<td>Products of textile, leather, fur</td>
<td>0.0616*</td>
<td>0.0216</td>
<td>0.0008*</td>
<td>-11.145*</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(2.110)</td>
<td>(0.130)</td>
<td>(10.701)</td>
<td>(-4.088)</td>
<td></td>
</tr>
<tr>
<td>Metal products</td>
<td>0.4042</td>
<td>-0.0238</td>
<td>0.0010*</td>
<td>-3.064*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(1.679)</td>
<td>(-0.187)</td>
<td>(11.296)</td>
<td>(-1.614)</td>
<td></td>
</tr>
<tr>
<td>Industrial machinery</td>
<td>0.1714*</td>
<td>-0.1411</td>
<td>0.0016*</td>
<td>-12.659*</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>(3.000)</td>
<td>(-0.895)</td>
<td>(14.132)</td>
<td>(-4.159)</td>
<td></td>
</tr>
<tr>
<td>Motor vehicles and transport equipment</td>
<td>0.0058</td>
<td>-0.0157</td>
<td>0.0005*</td>
<td>1.172</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(0.478)</td>
<td>(-0.408)</td>
<td>(7.852)</td>
<td>(0.956)</td>
<td></td>
</tr>
<tr>
<td>Telecom and electronics</td>
<td>0.2594*</td>
<td>-0.2078</td>
<td>0.0017*</td>
<td>-25.088*</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(3.632)</td>
<td>(-1.164)</td>
<td>(8.157)</td>
<td>(-4.573)</td>
<td></td>
</tr>
<tr>
<td>Furniture, arts and sport articles</td>
<td>0.0509*</td>
<td>-0.4998</td>
<td>0.0008*</td>
<td>-7.278*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(2.048)</td>
<td>(-0.510)</td>
<td>(11.184)</td>
<td>(-4.015)</td>
<td></td>
</tr>
</tbody>
</table>

t-values in parentheses, * denotes significance at 5%.

Table 2.4 shows the regression results of the impact of university R&D on the number of exporting firms. 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 2.4 Effects of accessibility to university R&D on the number of exporting firms

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Intra-regional accessibility to university R&amp;D</th>
<th>Inter-regional accessibility to university R&amp;D</th>
<th>Size</th>
<th>Constant</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>All commodities</td>
<td>0.0090</td>
<td>-0.0103</td>
<td>0.0049*</td>
<td>-48.656*</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>(0.276)</td>
<td>(-0.353)</td>
<td>(10.124)</td>
<td>(4.252)</td>
<td></td>
</tr>
<tr>
<td>Agricultural and food products</td>
<td>0.0009</td>
<td>0.0013</td>
<td>0.0003*</td>
<td>-3.281*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(0.337)</td>
<td>(0.324)</td>
<td>(14.167)</td>
<td>(-5.347)</td>
<td></td>
</tr>
<tr>
<td>Mineral based products</td>
<td>0.0014</td>
<td>0.0029</td>
<td>0.0005*</td>
<td>-4.972*</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(0.337)</td>
<td>(0.481)</td>
<td>(13.723)</td>
<td>(-5.287)</td>
<td></td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.0081</td>
<td>0.0067</td>
<td>0.0019*</td>
<td>-10.954*</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>(0.880)</td>
<td>(0.559)</td>
<td>(14.220)</td>
<td>(-6.341)</td>
<td></td>
</tr>
<tr>
<td>Products of wood and paper</td>
<td>0.0035</td>
<td>-0.0014</td>
<td>0.0017*</td>
<td>-22.038*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(0.257)</td>
<td>(-0.112)</td>
<td>(7.235)</td>
<td>(-3.958)</td>
<td></td>
</tr>
<tr>
<td>Products of textile, leather, fur</td>
<td>-0.0013</td>
<td>0.0067</td>
<td>0.0010*</td>
<td>-11.301*</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>(-0.155)</td>
<td>(0.565)</td>
<td>(10.237)</td>
<td>(-5.124)</td>
<td></td>
</tr>
<tr>
<td>Metal products</td>
<td>-0.0008</td>
<td>0.0003</td>
<td>0.0009*</td>
<td>-3.271</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(-0.117)</td>
<td>(0.003)</td>
<td>(13.349)</td>
<td>(-2.145)</td>
<td></td>
</tr>
<tr>
<td>Industrial machinery</td>
<td>0.0126</td>
<td>0.0043</td>
<td>0.0017*</td>
<td>-14.585*</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>(0.883)</td>
<td>(0.328)</td>
<td>(13.624)</td>
<td>(-5.115)</td>
<td></td>
</tr>
<tr>
<td>Motor vehicles and transport equipment</td>
<td>0.0003</td>
<td>-0.0006</td>
<td>0.0005*</td>
<td>1.032</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>(-0.121)</td>
<td>(8.259)</td>
<td>(0.844)</td>
<td></td>
</tr>
<tr>
<td>Telecom and electronics</td>
<td>0.0217</td>
<td>0.0057</td>
<td>0.0019*</td>
<td>-27.927*</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>(1.388)</td>
<td>(0.410)</td>
<td>(7.169)</td>
<td>(-4.486)</td>
<td></td>
</tr>
<tr>
<td>Furniture, arts and sport articles</td>
<td>-0.0009</td>
<td>0.0009</td>
<td>0.0009*</td>
<td>-7.868*</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>(-0.152)</td>
<td>(0.125)</td>
<td>(10.420)</td>
<td>(-4.252)</td>
<td></td>
</tr>
</tbody>
</table>

t-values in parentheses, * denotes significance at 5%.
The final measure of export diversity examined in this paper is the number of destinations of the aggregate 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 are presented in Tables 2.5 and 2.6 below. Starting with company R&D (Table 2.5), the regression estimates show 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 commodity groups (telecom, chemicals and industrial machinery) but also for agricultural and food products as well as for textiles. Just as in the regressions explaining the number of export varieties, 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 its own functional region but with the accessibility to R&D undertaken by firms in other regions.

The regressions including the accessibility to university R&D (Table 2.6) yields similar results as those including company R&D. 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 2.5 Effects of accessibility to company R&D on the number of export destinations

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Intra-regional accessibility to company R&amp;D</th>
<th>Inter-regional accessibility to company R&amp;D</th>
<th>Size</th>
<th>Constant</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>All commodities</td>
<td>0.0923*</td>
<td>0.3951*</td>
<td>0.0002*</td>
<td>50.930*</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>(3.032)</td>
<td>(4.040)</td>
<td>(2.860)</td>
<td>(19.111)</td>
<td></td>
</tr>
<tr>
<td>Agricultural and food products</td>
<td>0.0248*</td>
<td>0.1048*</td>
<td>0.0001*</td>
<td>4.1351*</td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>(2.446)</td>
<td>(2.371)</td>
<td>(10.765)</td>
<td>(5.324)</td>
<td></td>
</tr>
<tr>
<td>Mineral based products</td>
<td>0.0188</td>
<td>0.1279*</td>
<td>0.0002*</td>
<td>6.6376*</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>(1.002)</td>
<td>(2.550)</td>
<td>(4.352)</td>
<td>(5.673)</td>
<td></td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.0779*</td>
<td>0.2756*</td>
<td>0.0002*</td>
<td>18.739*</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>(3.001)</td>
<td>(2.783)</td>
<td>(4.611)</td>
<td>(8.886)</td>
<td></td>
</tr>
<tr>
<td>Products of wood and paper</td>
<td>0.0483</td>
<td>0.1184</td>
<td>0.0002*</td>
<td>21.851*</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>(1.304)</td>
<td>(1.833)</td>
<td>(7.960)</td>
<td>(11.398)</td>
<td></td>
</tr>
<tr>
<td>Products of textile, leather,</td>
<td>0.0476*</td>
<td>0.1183</td>
<td>0.0002*</td>
<td>10.237*</td>
<td>0.43</td>
</tr>
<tr>
<td>fur</td>
<td>(2.535)</td>
<td>(1.922)</td>
<td>(3.988)</td>
<td>(7.546)</td>
<td></td>
</tr>
<tr>
<td>Metal products</td>
<td>0.0068</td>
<td>0.1824*</td>
<td>0.0002*</td>
<td>19.526*</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>(0.300)</td>
<td>(2.606)</td>
<td>(3.971)</td>
<td>(10.886)</td>
<td></td>
</tr>
<tr>
<td>Industrial machinery</td>
<td>0.0695*</td>
<td>0.3118*</td>
<td>0.0002*</td>
<td>29.781*</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>(2.629)</td>
<td>(3.048)</td>
<td>(2.771)</td>
<td>(11.638)</td>
<td></td>
</tr>
<tr>
<td>Motor vehicles and transport</td>
<td>0.0138</td>
<td>0.1777*</td>
<td>0.0001*</td>
<td>8.8422*</td>
<td>0.43</td>
</tr>
<tr>
<td>equipment</td>
<td>(0.703)</td>
<td>(3.563)</td>
<td>(2.870)</td>
<td>(6.326)</td>
<td></td>
</tr>
<tr>
<td>Telecom and electronics</td>
<td>0.1607*</td>
<td>0.3236*</td>
<td>0.0002*</td>
<td>19.083*</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>(6.510)</td>
<td>(3.745)</td>
<td>(2.571)</td>
<td>(8.742)</td>
<td></td>
</tr>
<tr>
<td>Furniture, arts and sport articles</td>
<td>0.0153</td>
<td>0.1338*</td>
<td>0.0002*</td>
<td>10.818*</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>(0.775)</td>
<td>(2.651)</td>
<td>(4.408)</td>
<td>(8.576)</td>
<td></td>
</tr>
</tbody>
</table>

_t-values in parentheses, * denotes significance at 5%._
Table 2.6 Effects of accessibility to university R&D on the number of export destinations

<table>
<thead>
<tr>
<th>Commodity Group</th>
<th>Intra-regional accessibility to university R&amp;D</th>
<th>Inter-regional accessibility to university R&amp;D</th>
<th>Size</th>
<th>Constant</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>All commodities</td>
<td>0.0087* (1.564)</td>
<td>0.0452* (4.297)</td>
<td>0.0003*</td>
<td>52.266* (19.396)</td>
<td>0.40</td>
</tr>
<tr>
<td>Agricultural and food products</td>
<td>0.0034 (1.746)</td>
<td>0.0012* (2.459)</td>
<td>0.0001*</td>
<td>4.444* (6.131)</td>
<td>0.52</td>
</tr>
<tr>
<td>Mineral based products</td>
<td>0.0017 (0.507)</td>
<td>0.0130* (2.288)</td>
<td>0.0002*</td>
<td>7.234* (6.074)</td>
<td>0.38</td>
</tr>
<tr>
<td>Chemical products</td>
<td>0.0112* (2.357)</td>
<td>0.0286* (3.156)</td>
<td>0.0002*</td>
<td>19.881* (9.823)</td>
<td>0.37</td>
</tr>
<tr>
<td>Products of wood and paper</td>
<td>0.0039 (0.660)</td>
<td>0.0137 (1.888)</td>
<td>0.0003*</td>
<td>22.267* (11.492)</td>
<td>0.39</td>
</tr>
<tr>
<td>Products of textile, leather, fur</td>
<td>0.0044 (1.221)</td>
<td>0.0115 (1.951)</td>
<td>0.0002*</td>
<td>10.851* (8.212)</td>
<td>0.42</td>
</tr>
<tr>
<td>Metal products</td>
<td>-0.0018 (-0.427)</td>
<td>0.0146 (1.868)</td>
<td>0.0002*</td>
<td>20.672* (11.088)</td>
<td>0.29</td>
</tr>
<tr>
<td>Industrial machinery</td>
<td>0.0051 (0.888)</td>
<td>0.0360* (3.468)</td>
<td>0.0003*</td>
<td>30.830* (11.930)</td>
<td>0.35</td>
</tr>
<tr>
<td>Motor vehicles and transport equipment</td>
<td>-0.0019 (-0.675)</td>
<td>0.0196* (3.233)</td>
<td>0.0002*</td>
<td>9.534* (6.403)</td>
<td>0.42</td>
</tr>
<tr>
<td>Telecom and electronics</td>
<td>0.0198* (3.823)</td>
<td>0.0418* (4.195)</td>
<td>0.0002*</td>
<td>19.813* (9.408)</td>
<td>0.50</td>
</tr>
<tr>
<td>Furniture, arts and sport articles</td>
<td>-0.0003 (-0.103)</td>
<td>0.0137* (2.638)</td>
<td>0.0002*</td>
<td>11.423* (9.115)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

T-values in parentheses, * denotes significance at 5%.
A final issue to consider is the explanatory power of the different specifications of the estimated regression model. The highest explanatory power is obtained when applying the model on the number of exporting firms (Tables 2.3 and 2.4). 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 models. 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 (Tables 2.5 and 2.6). In these regressions the R-square values range from 0.30 to 0.52, whereas the regressions focusing on the number of export varieties yields R-square values between 0.44 and 0.75.

5. Summary and concluding remarks

This paper examines the influence of intra-regional and inter-regional accessibility to R&D on the diversity of export from Swedish municipalities. The hypothesis that accessibility to R&D activities in the private business sector, on the one hand, and university research departments, on the other hand, increases regional export diversity is tested in a spatial regression analysis based on export data for firms located in different municipalities. The econometric analysis includes three different indicators of export diversity; the number of exported goods, the number of exporting firms and the number of export destination. Moreover, regressions are estimated both for aggregate municipality export and for ten separate commodity groups.

The empirical results indicate that all three indicators of regional export diversity are positively affected by the intra-regional accessibility to company R&D in those commodity groups that have a relatively high R&D-intensity in production, such as chemical products, telecom and electronics and industrial machinery. Furthermore, the inter-regional accessibility to company R&D has a significant positive impact on the number of export varieties 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 significant impacts. 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; telecom and chemicals. Focusing on the number of export destinations, regressions yield similar results as those focusing on the number of export goods; the inter-regional accessibility to university research has a significant impact in seven out of ten commodity groups, whereas the intra-regional accessibility is of significant importance in explaining variations in the geographical diffusion of exports across municipalities only for the two most R&D-intensive commodity groups.

The results of this study contrast with some previous empirical evidence of the role of intra-and inter-regional knowledge accessibility for the innovative capacity of different locations. When analyzing regional patterns of patent production, several studies conclude that it is primarily variations in intra-regional accessibility to knowledge that explains differences in patent records across regions (Jaffe, 1989; Jaffe, et al. 1993, Gråsjö, 2006, among others). The outcome of this analysis shows 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. Such linkages are likely to be important in industries that are not strongly concentrated in space. In fact, Braunerhjelm and Borgman (2008) show that in Sweden, knowledge intensive manufacturing sectors have a relatively weak spatial concentration. Still, this study shows that the spatial proximity is of significant importance for expanding the diversity of regional export flows of the most technologically advanced types of goods. The significance and extensions of inter-regional linkages for knowledge diffusion are important factors for understanding how knowledge networks are created and how these networks influence regional patterns of production and export. We believe that this is an important issue for further research.
References


Chapter 3:
R&D Accessibility and
Comparative Advantages in
Quality Differentiated Goods

Sara Johansson

Abstract

This paper analyzes the influences of human capital and technology transfers from R&D activities on spatial export specialization along the range of product quality. This study contributes to previous research on specialization and trade in quality differentiated goods by addressing the influence of spatial knowledge flows on the observed geographical patterns of quality specialization. A theoretical model of endogenous quality choice derives regional comparative advantages to the presence of external knowledge flows from R&D activities. The potential of such knowledge transfers is modeled by accessibility variables, which deduce the potential of knowledge spillover from R&D activities to the geographical distribution of such activities and the observed patterns of spatial interaction. The impacts of regional R&D accessibility on regions’ revealed comparative advantages in production of high quality goods are subsequently examined in a regression analysis based on data cross-tabulated on industries and municipalities. The results of this empirical work show significant positive effects of knowledge and R&D accessibility on the revealed comparative advantages in production of high quality goods in Swedish regions. The empirical analysis also provides evidences of technology spillovers from abroad, as the presence of multinational firms stimulate specialization in high-quality product segments.

JEL: F12, F14, R12, R32
Keywords: product quality, vertical differentiation, knowledge, accessibility, spatial dependence, comparative advantage, technology

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I. Introduction

The importance of technology and innovation in explaining trade patterns was noticed already in the 1960s when theories of technology gaps and product life cycles were introduced by, Posner (1961), Vernon (1966) and Hirsch (1967). Posner suggested that differences in countries’ technological knowledge were an important factor in explaining trade patterns and that technological knowledge depends on investments in R&D. By introducing a dynamic perspective on comparative advantages, Posner enlarged the contemporary theoretical tradition, which regarded trade patterns as a static result of differences in countries’ fixed factor endowments. It is today widely recognized that regions and countries may create comparative advantages through purposeful investments in new technologies and in R&D (Fagerberg, 1995; Bernard et al. 1999; Sterlacchini, 1999 ; 2001; Bleaney and Wakelin. 2002; Barrios et al. 2003; Braunerhjelm and Thulin, 2008). Moreover, the new theory of trade and specialization emphasizes the role of economic geography as a determinant of long-term patterns of location and trade. Of particular interest in this vein of literature are the effects of knowledge and technology spillovers on specialization patterns (Grossman and Helpman, 1991; Coe et. al, 1996; Andersson, 1998; among others). Moreover, the presence of localized knowledge spillovers induces a concentration of R&D activities to certain regions, which may play a fundamental role in shaping spatial patterns of comparative advantage and subsequent trade specialization.

The influences of factor endowments and technology differences on trade patterns attained renewed interest in the 1990s, when a number of empirical studies showed that the majority of intra-industry trade flows consist of vertically differentiated goods, i.e. products of different levels of quality (Torstensson, 1991, Greenaway et al. 1994, 1995, Freudenberg et al. 1998, Martin and Orts, 2001, among others). Within product groups, countries seem to specialize in different quality segments. The economic concept of product quality in this literature adheres to Lancaster’s conceptualization of a product as a bundle of characteristics. A product variety that has a larger amount of every characteristic than the other varieties in the same product group is regarded as a variety of superior quality since it yields higher utility to the consumer. As pointed out by Kilkenny and Thisse (1999), differentiation of products in characteristic space appear to be of major importance in the globalized economy, since differentiation in characteristic space substitutes for the more traditional type of differentiation by geographic location.
The main theoretical explanation to international specialization and trade in quality differentiated goods is the same as for inter-industry trade, namely factor proportions and comparative advantages (Falvey, 1981; Shaked and Sutton, 1984; Flam and Helpman, 1987; Falvey and Kierzkowski, 1987; Davis, 1995). Given that factor proportions differ between goods of high and low qualities, dissimilarities in countries’ factor endowments may explain specialization and trade in quality differentiated goods. Moreover, cross-country heterogeneity in production technologies generates comparative advantages not only at the industry level but also along the quality spectrum of commodities belonging to a given product group.

This paper analyzes the importance of regional technology advantages and human capital inputs on the revealed comparative advantages in production of high-quality goods in Swedish municipalities (local government areas). A specific attention is given to the importance of knowledge spillovers as a source of such comparative advantages. The question asked is whether municipalities with a relatively high share of highly educated workers in manufacturing employment and good accessibility to R&D workers have a larger share of high quality goods in their aggregate export flow than the average region. This empirical analysis attempts to answer this question through a regression analysis based on data that are cross-tabulated across municipalities and sectors. The study focuses entirely on manufacturing sectors and makes use of firm-level data on export and import to identify product quality levels. Firm-level observations are subsequently aggregated to the levels of municipalities and sectors and used to calculate a regional index of revealed comparative advantage in production of high quality product varieties.

To my knowledge, there are no previous studies of the geographical distribution of production and export of quality differentiated goods within countries. Previous empirical work on trade in quality differentiated goods are conducted at the level of nations, using cross-country trade data. These studies show that the share of vertical intra-industry trade in aggregate trade flows differs between industries since the national relative factor endowment creates comparative advantages for some industries and comparative disadvantages for others (Torstensson, 1991; Chiarlone, 2000; Martin and Orts, 2001). Still, cross-country differences in factor proportions or factor productivity can not explain heterogeneity in product quality levels within industries in the same country. Observations from Swedish firm level data reveal an extensive variability in the quality of exported goods within the same narrowly defined product group. This observation suggests that, in so far as factor proportions or technological factors can explain vertical product differentiation, spatial heterogeneity in factor endowments or regional
technology advantages should be of larger importance than national factors in explaining the position of the individual firm along the product quality range.

Still, several studies have analyzed the impact of R&D activities and knowledge spillovers on other aspects of export performance. Zhao and Li (1997) find positive influences of R&D on the export propensity of Chinese firms and Barrios et al. (2003) report similar results from micro-data analysis of British firms. Studies presented by Braunerhjelm (1998) and Edquist et al. (1998) point to the fact that at the aggregate level, high share of R&D spending in total production may co-exist with a relatively low share of high-tech goods in total export. On the level of regions, Bresci and Palma (1999) present evidence of localized knowledge flows in Italian exports as they find that both exports and patenting activities in high-technology sectors are more spatially concentrated than in the manufacturing sector as a whole. Johansson and Karlsson (2007) find similar evidence of localized knowledge spillovers in an analysis of the impact of knowledge spillovers from R&D on regional export diversity. Gräsjö, (2006) shows that the aggregate export value and the number of export goods with a particularly high value are positively affected by accessibility to regional R&D activities. These knowledge spillovers appear to be more pronounced within regions rather than between regions. Andersson and Ejermo (2005) find that the degree of technological specialization increases both the total export value and the average export prices in Swedish regions. In sum, these studies indicate that localized knowledge flows have significant influences on the export performance of firms in different locations.

Given the focus of previous theoretical and empirical work in this field, this study contributes to the existing literature in three ways. First, it addresses the issue of specialization and trade in quality differentiated goods on the regional (municipal) rather than the national level. Second, the empirical estimations include variables reflecting the presence of spatial knowledge transfers from R&D activities. The predominant focus on R&D rather than just the average level of human or physical capital is motivated by previous empirical findings, which indicate that production of all types of differentiated goods is fairly intensive in human capital, whereas vertical product differentiation, i.e. production of varieties of high quality is more R&D intensive than production of low quality varieties (Chiarlone 2000; Martin and Orts, 2001; Ferragin and Pastore, 2005; Faruq, 2006). However, no previous study has included spatial knowledge flows in an analysis of the pattern of specialization along the product quality spectrum. A third novelty in this analysis is the use of firm-level data instead of data aggregated to product groups in the assessment of product quality. Product quality levels
are identified by the conventional method of unit price comparisons, but in contrast to previous studies this analysis is based on firm-level observations of unit prices rather than on average prices calculated at aggregate product groups. The extensive variability in firm-level unit prices observed in the data used in this study indicates that data on aggregate product groups are likely to generate aggregation biases in the approximation of product quality (Fontagné and Freudenberg, 1997). Consequently, firm-level data should generate more accurate quality information.

This study begins with a theoretical section, presenting a model where spatial comparative advantages in production of high quality products are derived from the profit maximization problem of the representative firm. Section 3 presents the empirical methodologies applied to approximate product quality and to identify the presence of spatial knowledge flows. This section also specifies the two-dimensional regression model used to test the hypothesis of a positive impact of regional human capital inputs and technology transfers from R&D activities on regional comparative advantages in production of high quality goods. Some descriptive statistics and the results of the regression analysis are presented in Section 4. Finally, Section 5 summarizes and concludes the outcomes of this analysis.

2. Theories of trade in quality differentiated goods

Theoretical work on trade in quality differentiated goods dates back to Linder (1961) who suggests that trade patterns are driven by demand-side rather than supply-side factors. Recent work by Fan (2005) and Hallak (2005) find support for the Linder hypothesis, presenting evidences of a positive relationship between per capita income and demand for high-quality goods. The predominant part of theoretical work on trade and specialization in vertically differentiated goods focuses, however, on pure supply-side factors. Falvey (1981) and Falvey and Kierzkowski (1987) propose that differences in factor proportions are the driving forces behind vertical specialization. Several empirical studies confirm that the average quality level of export goods increases with per capita income. The authors of these studies interpret this finding as an indication of a positive relationship between relative abundance of physical and human capital and specialization in relatively high-quality goods (Torstensson, 1991; Hummels and Klenow, 2002; Reganati and Pittiglio, 2005). Further investigations of relationships have revealed that that the stock of physical capital stimulates the average quality in aggregate export flows (Faruq 2006). The significance of human
capital effects on vertical specialization, on the other hand, varies between different empirical studies. Ferragina and Pastore (2005) and Martín and Orts (2001) suggest that production of both horizontally and vertically differentiated goods are positively influenced by human capital whereas production of vertically differentiated commodities are significantly amplified by R&D investments.

Flem and Helpman (1987) and Davis (1995) suggest that productivity differences driven by technology factors give rise to traditional Ricardian comparative advantages and specialization along the range of product quality. Davis (1995) argues that when the number of differentiated varieties is large there are extensive substitution possibilities across goods in production. In this case, small differences in production technology may have large impacts on firm-level profitability, which induces specialization and trade. Empirical support in favor of the technology hypothesis is provided by Faruq (2006), who detects positive influences of R&D spending and number of R&D workers on the average quality of aggregate export flows in a cross-country analysis of 58 countries. Martín and Orts (2001) find that the share of high-quality goods in export flows from different industries in Spain increases with the amount of R&D spending in the industry. Moreover, the possibility of technology spillovers from multinational enterprises has been examined by Faruq (2006) and Reganati and Pittiglio (2005), who find that FDI inflows have a positive effect on the average quality level in aggregate export flows. This finding adheres to the literature on international knowledge diffusion, which gives prominence to multinational enterprises as disseminators of technological knowledge across national boarders (Blomström and Kokko, 1997; Sjöholm, 1999; Keller and Yeaple, 2003; Ekholm, 2004; among others).

2.1 Endogenous quality choice

The theoretical concept of comparative advantages relies on cross-country differences in pre-trade relative prices, which provide a basis for specialization and trade. According to traditional trade theory differences in pre-trade relative prices of goods arise because of differences in relative factor prices (Heckscher-Ohlin) or because of differences in production technology (Ricardo). Both these theoretical approaches explain trade patterns with location-specific differences in production costs. The factor proportion theory derives the sources of cost advantages to differences in relative factor endowments, whereas the classical Ricardian model deduces cost advantages to differences in factor productivity. A large number of empirical studies have traced such productivity differences between
countries as well as firms to differences in knowledge and R&D investments (Weiser, 2005).

Andersson (1998) formalizes the idea of comparative advantages arising from regional technology differences in a model where the choice of product quality by the representative firm is endogenously determined. Andersson (1998) points out that a primary incentive for firms to employ human capital and conduct R&D is to increase the sophistication and complexity of their own products. The aim of this process is to achieve some functional attributes of the products that increase consumers’ willingness to pay for them. Hence, the choice of product quality is partly dependent on the marginal productivity condition of the knowledge input necessary to produce a high quality product.

Moreover, Andersson (1998) argues that the firm-level input of knowledge or human capital is not always sufficient to influence consumers’ willingness to pay for the firm’s output. This is due to the ongoing globalization of R&D and innovation processes, notably within the frameworks of multinational company groups. The importance of external sources of knowledge as a complement to firms’ internal knowledge, has been stressed also by (Malecki, 1997; Amin and Cohendet, 1999; Kuemmerle, 1999). Since all knowledge handlers have their specific location in geographical space, knowledge exchange mainly takes place through interaction within various spatial “knowledge” networks. Geographically, these networks may be local, intra-regional, inter-regional or international and by having one or several nodes in common these networks are interlinked in multiple ways. As a consequence, the traditional marginal productivity conditions are no longer satisfactory for determining the optimal production strategy of the individual firm, but conditions for interaction with other producers and, in particular, R&D activities are becoming increasingly important. As an extension of the traditional theory of the firm, Andersson (1998) derives a marginal interactivity condition that relates the degree of interaction to the transaction cost of such interaction.

This study applies the model of endogenous quality choice developed by Andersson (1998) with some modifications. It is assumed that the willingness to pay for a given commodity depends on the amount of knowledge embodied in it. Accordingly, the market price \( P_s \) for a given product variety, produced by the representative firm in region \( s \), is a function of the firm’s own input of human capital, \( K_s \), and of external knowledge absorbed from R&D activities located in the own region and in all other regions \( I_r \) \( (r = 1,\ldots,n) \). This external knowledge is a public good that arises as
an externality from R&D conducted in universities and in the private business sector. For simplicity it is assumed that internal and external knowledge only affect the quality level of output, whereas the quantity of output is a function of input of low-skilled labor, $L_s$. The level of quality aspired by the individual firm is then endogenously determined by the first order conditions for profit maximization. The profit maximization problem of the representative firm located in region $s$ is formulated as:

$$\max \pi_s = P_s(K_s, I_s, \ldots, I_{m_s})Q_s(L_s) - r_sK_s - w_sL_s - \sum r_i I_i,$$

where $P(.)$ and $Q(.)$ are assumed to be concave, continuous and differentiable functions. $r$ and $w$ are the input prices of human capital and low-skilled labor respectively and $r_i$ is the cost of interaction with economic agents in another region $r$, i.e. the transaction cost of absorbing external knowledge flows from region $r$. The conventional marginal productivity conditions from this maximization problem are:

$$\frac{\partial \pi_s}{\partial K_s} = \frac{\partial P_s}{\partial K_s} Q_s - r_s = 0 \quad (2.a)$$

$$\frac{\partial \pi_s}{\partial L_s} = P_s \frac{\partial Q_s}{\partial L_s} - w_s = 0 \quad (2.b)$$

Equations 2.a and 2.b state that, conditional on factor prices, inputs of human capital and low-skilled labor in region $s$ depend on the marginal productivity of knowledge input, i.e. the economic efficiency of the innovation process, and the marginal productivity of low-skilled labor, i.e. the efficiency of the production process. Equation 2.a implies the input price per efficiency unit of knowledge determines the optimal input of knowledge and thereby the product quality level aspired by the representative firm. If factors are mobile and factor markets are perfectly competitive, factor prices should reflect the marginal productivity of the factor in question, implying that significant regional differences in the marginal productivity conditions would not appear. If human capital, on the other hand, is a factor that is to some extent geographically trapped, spatial differences in factor costs may occur. Besides poor factor mobility, factor markets can also be distorted by wage legislation or other institutional factors. Under these circumstances firms in locations with a relatively low input price per efficiency unit of human capital will have a cost advantage in production of high quality products and one would expect to distinguish a spatial pattern of specialization along the spectrum of product qualities.
In addition to the conventional marginal productivity conditions, the optimal input of external knowledge is given by the marginal interactivity condition:

\[
\frac{\partial \pi_r}{\partial l_{rs}} = \frac{\partial P_r}{\partial l_{rs}} Q_s - \tau_{rs} = 0
\]  

(3)

Equation 3 shows that the optimal input of external knowledge depends on the marginal effect of this input on the market price of output and the transaction cost of acquire and implement such external knowledge. The transaction cost of external knowledge flows between two regions, \(\tau_{rs}\), is assumed to be an increasing function of geographical distance, i.e. travel-time distance, which reduces the efficiency of intra-regional and inter-regional interactions. This follows from the theoretical conjecture that new knowledge generated by R&D tends to be tacit and sticky in the sense that it is difficult to codify. The diffusion of new knowledge is therefore dependent on interpersonal contacts and the frequency of such contacts tends to decrease with the time distance between the agents involved (Pred, 1966; Feldman, 1994). Thus, the transmission and absorption of technological and scientific knowledge is facilitated by geographical proximity. In fact, a large number of empirical studies indicate that knowledge flows are bounded in geographical space (Jaffe, 1989, Jaffe, et al. 1993, Anselin et al. 1997; Breschi and Palma. 1999). This implies that the marginal interactivity condition in Equation 3 may differ significantly between regions and regions that are well spatially connected with R&D abundant regions may have cost advantages in absorbing external knowledge. Assuming further that the marginal effect of external knowledge flows on the willingness to pay takes the form:

\[
\frac{\partial P_r}{\partial l_{rs}} = R^\gamma J_{rs}^{-\lambda} \quad 0 < \gamma < 1, \quad 0 < \lambda < 1
\]  

(4)

where \(R_r\) is the size of R&D activities in region \(r\) and the parameters \(\gamma\) and \(\lambda\) reflects the impact of external knowledge flows on the product price. By using Equation 3 and 4, the expected flow of knowledge from region \(r\) to region \(s\) can be expressed as:

\[
I_{rs} = R^\gamma J_{rs}^{\lambda - 1/\lambda} r_{rs}^{-1/\lambda}
\]  

(5)

Equation 5 shows that the expected knowledge flow from region \(r\) to region \(s\) increases with the amount of R&D in region \(r\) and with the quantity of goods produced in region \(s\), but decreases with the transaction cost of
acquiring this external knowledge. Furthermore, assume that this transaction cost increases with geographical distances in a non-linear way:

$$\tau_{rs} = \exp\{\sigma t_{rs}\}$$ (6)

where $t_{rs}$ is the travel-time distance between the two regions and $\sigma$ is a time-sensitivity parameter. The knowledge flow from region $r$ to region $s$ is then approximated by:

$$I_{rs} = (R'_r \exp \{-\sigma t_{rs}\}Q_s)^{\gamma/\lambda}$$ (7)

Equation 7 shows that the optimal input of external knowledge in the production process is largely dependent on the knowledge geography of the location of the individual firm. Moreover, the first terms on the right hand side of Equation 7, $(R'_r \exp \{-\sigma t_{rs}\})$, have the same properties as conventional accessibility measures, which have been frequently used to reflect spatial spillover effects in recent empirical work, e.g. Johansson and Karlsson (2007), Gråsjö (2006), Andersson, Gråsjö and Karlsson (2006) Ejermo (2004) and Niebuhr (2003). The accessibility concept is more thoroughly discussed in the next chapter.

2.2 Hypotheses

The simple model of endogenous quality choice outlined above provides two explanations of how spatial comparative advantages along the product quality spectrum arise. First, the marginal productivity condition in Equation 2a states that regions with a relatively low input price per efficiency unit of human capital have a comparative advantage in the production of high quality goods. Second, the marginal inter-activity condition in Equation 3 demonstrates that regions with good accessibility to R&D have comparative advantages in the production of high quality goods because of lower costs of interaction, which intensifies spatial knowledge flows. From the theoretical model of endogenous quality choice we may formulate two testable hypotheses:

- The level of product quality is increasing with the input of human capital.
- Localized spillovers from R&D activities stimulate spatial specialization in goods of high quality.
As discussed in the beginning of this section, previous empirical studies have shown that inflow of FDI stimulates the average quality level of exports. One reason to this positive influence on product quality of MNE activities is that multinational corporations provide a very specific type of network in which the potential for knowledge spillover are particularly high. Accordingly, numerous scholars attribute a specific role to MNE firms, namely that of international disseminators of knowledge and technology. In view of these previous studies, this paper also tests a third hypothesis:

- Knowledge and technology flows from multinational firms stimulate spatial specialization in high quality products.

The sequel of this paper tests these hypotheses with the use of a firm-level data set. Before exploring empirical results, a number of measurement issues are addressed in the following section.

3. Empirical Methodology

The hypotheses formulated in the previous section are tested in a cross-regional regression model estimated on the level of municipalities and industrial sectors. The analysis is, however, based on firm-level data of Swedish export for the years 1999 – 2003. This data set contains information about all firms’ total export value and export volume at the 8-digit level of product classification. With this detailed data, we define a product variety as a firm-specific observation on the 8-digit level of product classification. All firm-specific product varieties observed for a given 8-digit product classification is defined as a product group. These product groups can be further aggregated to the level of broad manufacturing sectors, classified according to industry classification codes (NACE). It is certainly the case that the importance of human capital and external information flows from R&D activities differs between product groups as well as industrial sectors. Accordingly, the regression analysis make use of the most detailed information when defining quality (see Section 3.1) but also includes an industry dimension when aggregating firm-level observations to the level of municipalities. The location of the firm is given at the municipality level, which gives 288 possible locations in Sweden. The size of R&D activities in each municipality is calculated using the average number of persons (full-time equivalents) holding a PhD that work with R&D in the private business sector in the years 1993, 1995 and 1999\textsuperscript{22}. The R&D data used in this study

\textsuperscript{22} The hypotheses are also tested using spatial data on R&D personnel in universities, however, the results of these estimations were not significant.
are not disaggregated to the level of sectors, and for this reason the aspect of sector-specific technological spillovers cannot be included in this analysis. In order to construct an accessibility measure, the values of the R&D indicator are discounted by distance decay functions based on travel-times between all municipalities in Sweden.

3.1 Defining product quality

An analytical framework for studying product differentiation was introduced in a series of papers by Lancaster (1966; 1975; 1979). According to Lancaster (1979) products having the same set of characteristics compose a product group. If varieties in the same product group have different proportions of characteristics but none has a larger amount of every attribute, varieties are horizontally differentiated. If a variety has a larger amount of every characteristic than have other varieties in the same product group, this variety is defined as qualitatively superior and is vertically differentiated from the other varieties in the product group.

In the literature of international trade differences in unit values of disaggregated products are assumed to reflect differences in product quality (Sutton, 1986; Abd-el-Rahman, 1991; Aiginger 1997). The rational for using unit values is that, assuming perfect information and utility maximizing consumers, a variety sold at a higher price must contain a larger amount of characteristics than a variety sold at a lower price. The intuition behind this statement is that market prices reflect customers’ willingness to pay for a given variety and with perfect information, consumers are willing to pay more for varieties that yield higher utility.

A common method for approximating product quality by using trade data is comparisons of average unit prices of export and import in narrowly defined product groups. This conventional method, introduced by Abd-el-Rahman (1991), is here applied at the level of exporting firms. Each firm is assumed to produce a differentiated product variety, \( k \), which belongs to a set, \( G \), of products having similar product characteristics. Thus index \( k \) refers to product variety whereas index \( G \) refers to product group. Firms’ export prices are compared to the average import price of varieties in the same product group and a variety that has an export price that exceeds the average

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23 Stiglitz, 1987, argues that when there is a presumed relationship between product quality and price, the price itself becomes a relevant product characteristic. For commodities where the price is the only characteristic distinguishing varieties before purchase, the relationship between price and quality must still hold to meet customer’s expectations about product quality. Hence, prices tend to reflect quality even when information is imperfect.
import price in the relevant product group by a certain percent is defined as a high quality product variety. The definition of a high quality product variety is formally given by:

\[
\frac{P^X_{\text{ex}}}{P^M_G} > 1 + d
\]  

(8)

The numerator in Equation 8 denotes the unit price of exports (superscript $X$) of variety $k$ belonging to product group $G$, and the denominator denotes the average unit price of imports (superscript $M$) of varieties belonging to product group $G$. $d$ is a dispersion factor, which corresponds to a price differential between varieties of average quality and varieties of higher qualities. Different values of the price dispersion factor have been used to distinguish high quality product varieties in previous empirical research. With the purpose of investigating the robustness of the empirical results for different specifications of high-quality goods, the subsequent regression analysis applies four different values of the price dispersion factor: 0.1, 0.25, 0.5 and 1. Moreover, aggregation biases have been minimized as unit values are calculated at the 8-digit level of product classification. Also geographical biases, originating from geographical variations in trade costs, have been avoided as the average unit values of import are calculated with respect to import from the EU countries only.

### 3.2 Revealing comparative advantages

The concept of comparative advantage is based on differences in pre-trade relative prices/costs, which provide a basis for specialization and trade. Since pre-trade relative prices are typically unobservable from trade data, the actual specialization of regions is assumed to reveal such comparative advantages at a given point in time. This identification of comparative advantage was introduced by Balassa (1966) and uses a region’s relative market share for a given sector/commodity as an indicator of revealed comparative advantages (RCA). A variation of this conventional Balassa-index is presented by Hoen and Oosterhaven (2006), who propose a deviation from mean approach in measuring revealed comparative advantages. In the context of regional specialization in high quality product varieties an RCA index, corresponding to that developed by Hoen and Oosterhaven (2006), is calculated as the share of high quality export in total regional export adjusted by the average share of high quality export in the aggregate export flow of the regions in a reference group. Since this study focuses on the spatial pattern of export specialization in goods of high quality, the share of high quality goods in the country’s aggregate export
The index is calculated separately for each 2-digit industry in the manufacturing sector, implying that it varies both across industries and municipalities according to:

\[
RCA_{j,s}^H = \left( \frac{V_{j,s}^H}{V_{j,s}} - \frac{\sum V_{j,s}^H}{\sum V_{j,s}} \right)
\]

where

\[
V_{j,s}^H = \sum_{t \in G} \sum_{k \in G} p_t^k Q_k^t I_k,
\]

\[
I_k = \begin{cases} 
1 & \text{if } \left( \frac{p_t^k}{p_{t,s}} \right) > 1 + d \\
0 & \text{otherwise}
\end{cases}
\]

and

\[
V_{j,s} = \sum_{t \in G} \sum_{k \in G} p_t^k Q_k^t \quad \forall k
\]

Hence, the term \( V_{j,s}^H \) is the total value of export of high-quality goods in sector \( j \) in municipality \( s \), and \( V_{j,s} \) is the total export value of sector \( j \) in municipality \( s \). The measure of RCA defined in Equation 9 has the properties of a symmetric distribution and a mean value of zero. It ranges from -1 to 1; larger than zero if the municipality has a revealed comparative advantage in production of high quality varieties and smaller than zero if the municipality has a revealed disadvantage in producing goods of high quality.

### 3.3 Measuring R&D accessibility

As discussed in Section 2, external knowledge flows from R&D activities are largely dependent on face-to-face interaction, which is facilitated by geographical proximity. Since the accessibility measure reflects the choice context for spatial interaction an accessibility approach is particularly well suited in modeling spatial knowledge flows (Weibull, 1976). It should be emphasized, though, that the measure of R&D accessibility does not measure the actual magnitude of knowledge transfers within and between regions but reflects a region’s potential to benefit from knowledge generated in its internal and external milieu. Gråsjö (2006) suggests that significant estimated effects of accessibility variables can be interpreted as evidences of spatial dependencies. Consequently, the inclusion of accessibility variables in econometric models also serves the purpose of modeling spatial dependencies that would otherwise generate inefficient, biased or inconsistent estimates due to un-modeled spatial autocorrelation. As shown by Gråsjö and Andersson (2006) the inclusion of accessibility variables in spatial regression models significantly reduces the incidence of spatial autocorrelation.
In this analysis, the amount of R&D conducted in a specific location is measured as the number of full-time working years devoted to R&D activities by persons holding a PhD degree, \( R \). The geographical proximity to those activities is measured through a distance decay function, \( f(c) \), which relates the accessibility value to the cost of reaching the R&D activities. A region’s accessibility to R&D is then defined as the sum of its internal accessibility to R&D and its accessibility to the R&D in all other regions in the set \( N = \{1, \ldots, n\} \) of regions:

\[
A^R_s = R_s f(c_{ss}) + \ldots + R_s f(c_{sn})
\]

Different researchers have used different specifications of the distance decay function, but one of the most common methods of spatial discounting is the use of an exponential function (Andersson & Johansson, 1995; Johansson & Klaesson, 2001). Here, the distance decay function is the inverse of the function of interaction costs in Equation 6:

\[
f(c_{ss}) = \exp\left(-\sigma_{ss}\right)
\]

where \( \sigma \) is a pre-estimated time-sensitivity parameter that reflects how the accessibility responds to changes in travel-times between regions, \( t_{ss} \).

Combining Equations 10 and 11, a region’s accessibility to R&D activities is defined as:

\[
A^R_s = 1 + \sum_{r=1}^{n} R_s \exp\left(-\sigma_{sr}\right)
\]

Moreover, a region can be defined as a functional region consisting of nodes (municipalities) that are connected by economic networks and networks of physical infra-structure (Andersson & Karlsson, 2001). Johansson (2002) describes a functional region as a region distinguished by its concentration of activities and of its infrastructure that facilitates a particularly high interaction frequency within its borders. The geographical extension of a functional region is determined by the spatial points where the main streams of interaction are shifted toward other regions (Johansson, 1993). Given these properties, the interaction to be considered in this analysis has three relevant parts; the local accessibility to R&D, the intra-regional accessibility

24 See Johansson, Klaesson and Olsson (2002) for a thorough analysis of time sensitivities in travels.

25 A measure of accessibility should satisfy certain criteria of consistency and meaningfulness. The measure used here satisfies those warranted criteria, derived by Weibull (1976).
to R&D and the inter-regional accessibility to R&D. The reason for separating the total accessibility into these three parts is that the time sensitivity, reflected by the parameter $\sigma$, differs between local, intra-regional and inter-regional interactions (Johansson, et al. 2002) 26. The three categories of R&D accessibilities are formally expressed as:

(i) Local accessibility:

$$AR_{ls} = \exp\left[-\sigma_1 t_{ls}\right] R_s$$  

(ii) Intra-regional accessibility:

$$AR_{ls} = \sum_{m \in M, l \neq s} \exp\left[-\sigma_2 t_{ls}\right] R_m$$

(iii) Inter-regional accessibility:

$$AR_{ls} = \sum_{m \in M, l \neq s} \exp\left[-\sigma_3 t_{ls}\right] R_m$$

Equations 13, 14 and 15 reveal that local accessibility is the sum of each municipality’s internal accessibility to R&D, the intra-regional accessibility refers to the sum of each municipality’s accessibility to R&D in all other municipalities within the own functional region, M, and the inter-regional accessibility is the municipality’s accessibility to R&D facilities in all locations outside region $M$. Equations 13-15 show that the accessibility measure reflects how inputs from other locations diminish with distance as the values of R&D activities are spatially discounted by the distance decay function.

### 3.4 Regression model

The theoretical framework developed in section 2 predicts that spatial variations in the input price of human capital and the geography of external knowledge sources create spatial comparative advantages along the product quality spectrum. These hypotheses are tested through estimations of a regression model that includes both a spatial and an industry dimension. The dependent variable, revealed comparative advantages in high quality goods ($RCA_{js}^{HQ}$), is defined for 2-digit manufacturing sectors (index $j$) for municipalities (index $s$). This regression model is specified accordingly:

$$RCA_{js}^{HQ} = \alpha + \beta_1 K_{js} + \beta_2 AR_{ls} + \beta_3 AR_{ls} + \beta_4 AR_{ls} + \beta_5 MNE_{js} + \beta_6 S_{js} + \delta_n D_j + \epsilon_{js}$$  

26 Local accessibility is defined within the range of several unplanned contacts per day, implying a time distance of maximum 15 minutes of travel, intra-regional accessibility regards the range in which contacts are made on a regular daily basis (commuting), implying a time distance of 15-50 minutes. The properties of the time sensitivity parameters are $\sigma_2 > \sigma_3 > \sigma_1$, see Johansson, Klaesson and Olsson (2002).
The explanatory variables of the model are human capital $K_{js}$, measured as the number of employees with at least three years of university education in sector $j$ in municipality $s$. The model also includes the accessibility variables, $AR_{js}$, $AR_{js}$, and $AR_{js}$, defined in Equations 13-15, which reflect potential spillovers from R&D activities. Moreover, the variable $MNE_{js}$ is the share of export accounted for by multinational firms, which provides a measure of potential knowledge transfers from foreign countries. Furthermore, the marginal interactivity condition in Equation 3, together with Equation 7, predicts that the importance of external knowledge flows increases with the quantity of output. Since the production volume is a function of labor input, the regression model includes a variable controlling for the relative size of the sector, measured in terms of employment. This variable, $S_{js}$, is defined as the municipality’s share of the country’s employment in the given sector. Finally, a vector of dummy variables ($D_j$) is also included to control for unobserved industry heterogeneity and $\varepsilon_{js}$ is an error term following the usual assumption of zero mean and constant variance. The definitions of the explanatory variables are summarized in Table 3.1.
Table 3.1 Explanatory variables

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{js}$</td>
<td>Internal knowledge</td>
<td>Number of employees (in thousands) in industry $j$ in municipality $s$ with at least three years of university education.</td>
</tr>
<tr>
<td>$AR_{ls}$</td>
<td>Local accessibility to R&amp;D</td>
<td>The amount of R&amp;D conducted within municipality $s$, weighted by the travel time distances within the municipality (in thousands units).</td>
</tr>
<tr>
<td>$AR_{ls}$</td>
<td>Intra-regional Accessibility to R&amp;D</td>
<td>The amount of R&amp;D conducted in other municipalities within the labor market region of municipality $s$, weighted by a time-travel distance matrix (in thousands units).</td>
</tr>
<tr>
<td>$AR_{ls}$</td>
<td>Inter-regional Accessibility to R&amp;D</td>
<td>The amount of R&amp;D conducted in municipalities outside the labor market region of municipality $s$, weighted by a time-travel distance matrix (in thousands units).</td>
</tr>
<tr>
<td>$MNE_{js}$</td>
<td>Presence of multinational firms</td>
<td>Share of the total export value from sector $j$ in municipality $s$ that is exported by a multinational firm.</td>
</tr>
<tr>
<td>$S_{js}$</td>
<td>Regional size of the sector</td>
<td>The share of the country’s employment in sector $j$ that is located in municipality $s$.</td>
</tr>
</tbody>
</table>

4. Empirical results

Before presenting the results of the regression analysis, this section begins with a presentation of some descriptive statistics of the spatial pattern of quality specialization. For the total manufacturing sector, the share of high quality goods in total manufacturing export varies depending on the definition of quality. Table 3.2 presents descriptive statistics of the share of high quality export in total regional export of manufactured goods $\left(\frac{V_{j}^{H}}{V_{j}}\right)$ according to the four alternative values of the price dispersion factor in Equation 8. The larger this dispersion factor, the larger the price differential between exported and imported product varieties. This is interpreted as a larger quality gap between exported and imported product varieties. The
third row in Table 3.2 shows that the average shares of high quality goods in Swedish export flows vary with the value of the dispersion factor used to identify high quality commodities. The mean share of high quality goods in manufacturing export in Swedish municipalities decreases the larger is the value of dispersion factor. Varieties with a unit export price that is 10 percent higher than the average import price of varieties in the same product group (the lowest above-average quality level considered in this study) account for about 54 percent of all regional export in the average municipality (first column in Table 3.2). Varieties with an export price that is twice as large as the corresponding import price only accounts for about 25 percent of regional export in the mean municipality (last column in Table 3.2). The minimum and maximum values of \( \frac{V_{ij}}{V_{kj}} \) follow the same patterns and decrease with the value of the dispersion factor. Independently of the value of the dispersion factor, there are large spatial variations in the degree of specialization in high quality products across.

Table 3.2 Percentage share of high-quality export in total municipality export

<table>
<thead>
<tr>
<th>Percentage share of municipality export value consisting of products with a relative export price:</th>
<th>( P_{xj}^k / P_{yj}^k &gt; 1.1 )</th>
<th>( P_{xj}^k / P_{yj}^k &gt; 1.25 )</th>
<th>( P_{xj}^k / P_{yj}^k &gt; 1.5 )</th>
<th>( P_{xj}^k / P_{yj}^k &gt; 2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>2.25</td>
<td>0.89</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>Maximum</td>
<td>99.04</td>
<td>94.69</td>
<td>92.71</td>
<td>90.94</td>
</tr>
<tr>
<td>Mean</td>
<td>53.97</td>
<td>45.62</td>
<td>35.50</td>
<td>24.67</td>
</tr>
<tr>
<td>St. Dev.</td>
<td>23.74</td>
<td>23.83</td>
<td>23.30</td>
<td>19.86</td>
</tr>
</tbody>
</table>

The shares of high quality goods in the aggregate export flow from different municipalities and industries \( \left( \frac{V_{ij}}{V_{kj}} \right) \) are used to construct an index of revealed comparative advantage according to Equation 9. Table 3.3 presents descriptive statistics of the revealed comparative advantage cross-tabulated across municipalities and sectors. This index is used as dependent variable in the regression model. By definition, this index has a mean value of zero, which is interpreted such that the average municipality has no advantage or disadvantage in production of high quality goods. The median deviates from zero, but as the figures in Table 3.3 reveal, this deviation is fairly small. The RCA index for highest quality levels (RCA 3 and RCA 4) have a larger maximum value than the RCA index based on smaller price-differentials in the definition of above-average quality (RCA 1 and RCA 2).
### Table 3.3 Regional revealed comparative advantages in production of high quality goods

<table>
<thead>
<tr>
<th>RCA 1: High quality products are defined as varieties with ( \frac{P^X_{kig}}{P^M_G} &gt; 1.1 )</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.52</td>
<td>0.45</td>
<td>0.01</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RCA 2: High quality products are defined as varieties with ( \frac{P^X_{kig}}{P^M_G} &gt; 1.25 )</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.45</td>
<td>0.49</td>
<td>-0.05</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RCA 3: High quality products are defined as varieties with ( \frac{P^X_{kig}}{P^M_G} &gt; 1.5 )</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.36</td>
<td>0.57</td>
<td>-0.04</td>
<td>0.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RCA 4: High quality products are defined as varieties with ( \frac{P^X_{kig}}{P^M_G} &gt; 2 )</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Median</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.25</td>
<td>0.66</td>
<td>-0.04</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Descriptive statistics of the independent variables of the model specified in Equation 16 is presented in Table 3.4. Of particular interest in this table are the figures for the variables human capital, R&D accessibility and MNE’s share of municipality export as these variables show a highly skewed distribution. This implies that the assumption of homoscedastic error terms is likely to be violated. The Breusch-Pagan test indicates that the error-term is heteroscedastic and White’s robust covariance matrix has, consequently, been used to adjust the standard OLS estimates.
Table 3.4 Descriptive Statistics of Explanatory Variables

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.000</td>
<td>5.60</td>
<td>0.017</td>
<td>0.131</td>
</tr>
<tr>
<td>Local Accessibility to R&amp;D</td>
<td>0.000</td>
<td>0.641</td>
<td>0.011</td>
<td>0.054</td>
</tr>
<tr>
<td>Intra-regional Accessibility to R&amp;D</td>
<td>0.000</td>
<td>0.382</td>
<td>0.023</td>
<td>0.056</td>
</tr>
<tr>
<td>Inter-regional Accessibility to R&amp;D</td>
<td>1.033E-07</td>
<td>0.169</td>
<td>0.015</td>
<td>0.020</td>
</tr>
<tr>
<td>MNE’s share of Export</td>
<td>0.000</td>
<td>1.000</td>
<td>0.015</td>
<td>0.093</td>
</tr>
<tr>
<td>The municipality’s share of total industry employment</td>
<td>5.966E-06</td>
<td>0.343</td>
<td>0.005</td>
<td>0.015</td>
</tr>
</tbody>
</table>

The theoretical framework presented in Section 2 advocates that regional export specialization along the quality spectrum is positively dependent on the input of highly educated workers (human capital), the absorption of external knowledge flows from R&D activities (R&D accessibility) and technological spillovers from multinational firms. The hypothesis of a positive impact of human capital input and technological spillovers from R&D activities and multinational firms on regional revealed comparative advantages is tested through estimations of the regression model in Equation 16. All variables, except the accessibility variables, are defined at the two-digit industry level in each municipality. With these properties, the data set contains 4072 sector-location specific observations and in the regression model the sector dimension is controlled for by inclusion of 2-digit industry dummies. The regression model is applied to the four different specifications of the dependent variable with the objective to investigate the robustness of the empirical results.

The regression results, presented in Table 3.5, show that input of human capital has a significant positive effect on regional RCA in all four specifications of the RCA index. However, the size of the estimated coefficient does not change substantially over the four different estimations, implying that the importance of human capital input does not increase significantly with the quality level considered. Hence, there is a significant positive influence of human capital input on production and export of differentiated varieties of all above-average qualities but from these results
we cannot confirm the hypothesis that product quality (defined by relative unit values) is an increasing function of human capital input. Still, these estimates support some previous empirical findings that indicate that both horizontal and vertical production differentiation are fairly intensive in human capital.

Moreover, the estimation results reported in Table 3.5 reveal that spatial variations in the degree of high-quality specialization are stimulated by external knowledge flows from R&D, approximated by the accessibility variables. The accessibility to R&D within the own municipality (local R&D accessibility) appear to have a significant influence on the specialization in the highest quality segments (RCA 3 and RCA 4), whereas the positive impact of intra-regional R&D accessibility on the revealed comparative advantage in production of high quality goods is significant in all specifications of the RCA index. The indication of a stronger influence of intra-regional R&D accessibility than of the local R&D accessibility are likely to be driven by the fact that many municipalities in Sweden do not host any measurable R&D activities within its borders. For these municipalities, the intra- and inter-regional knowledge geography is all that matters. The estimated coefficients for inter-regional R&D accessibility are positive but not significant in any of the regression specification.

Furthermore, the variable reflecting spillovers from foreign knowledge sources, the MNE’s share of the export from the sector in the region, shows a significant positive effect on the revealed comparative advantage in high quality export. Since the size of the estimated regression coefficient is reasonably robust over the four specifications of the RCA index, there is no obvious indication of an increased influence of MNE’s for stimulating specialization in the more superior quality segments.

The variable controlling for the relative size of the sector shows a significant negative effect on the municipality’s revealed comparative advantage in high-quality goods. This negative influence contradicts the theoretical prediction that input of internal and external knowledge is more profitable the larger the scale of production. One explanation to this finding is that high quality goods generally are produced and exported in smaller volumes than are standardized goods of average quality and the size variable may therefore have a negative impact on spatial quality specialization.
### Table 3.5 Impact of human capital and knowledge spillovers on revealed comparative advantages in high-quality goods

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Dependent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RCA 1</td>
</tr>
<tr>
<td>Constant</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
</tr>
<tr>
<td>Human Capital</td>
<td>0.180**</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
</tr>
<tr>
<td>Local R&amp;D Accessibility</td>
<td>0.130</td>
</tr>
<tr>
<td></td>
<td>(0.070)</td>
</tr>
<tr>
<td>Intra-regional R&amp;D Accessibility</td>
<td>0.306**</td>
</tr>
<tr>
<td></td>
<td>(0.075)</td>
</tr>
<tr>
<td>Inter-regional R&amp;D Accessibility</td>
<td>0.057</td>
</tr>
<tr>
<td></td>
<td>(0.239)</td>
</tr>
<tr>
<td>MNE’s share of Export</td>
<td>0.105*</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
</tr>
<tr>
<td>Municipality’s share of total industry employment</td>
<td>-2.182***</td>
</tr>
<tr>
<td></td>
<td>(0.813)</td>
</tr>
<tr>
<td>F-value (Significance)</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>4072</td>
</tr>
</tbody>
</table>

**Indicates significance at the 1-percent level, * indicates significance at the 5-percent level. Robust standard errors in parentheses. 2-digit industry dummies are included in all estimations but are not reported.

Considering the robustness of the results over the four different specifications of high quality product varieties, the signs of the coefficient estimates are robust for all variables. The sizes of the regression coefficients of local and intra-regional R&D accessibility increase with the price dispersion factor used in calculating the RCA index. This tendency signifies...
that knowledge flows from R&D has a stronger influence on revealed spatial advantages in the most advanced quality segments of manufactured products. These outcomes suggest that the importance of technology transfers from R&D activities on spatial specialization along the product quality spectrum is amplified by an increased quality level. However, the confidence intervals of the estimated coefficients for local and intra-regional R&D accessibility from the different regressions overlap each other. It is therefore difficult to draw any conclusions about a possibly growing importance of spillovers from R&D for higher quality levels.

Nevertheless, the regression results allow us to conclude that accessibility to R&D personnel in the private business sector in its own municipality and in municipalities within the own functional region stimulate a specialization of the local manufacturing sectors toward goods of a relatively high quality. Consistent with previous empirical findings, these spatial knowledge flows appear to be limited to the own functional region. These results support the hypothesis of significant positive effects of localized spillovers from R&D activities on spatial specialization in production of high quality varieties of manufactured goods.

5. Summary and Concluding Remarks

At the purpose of analyzing the influence of location-specific factors on the quality of exported goods, this paper examines the impact of knowledge input and regional technology advantages on municipalities’ revealed comparative advantages in the production of high quality varieties of manufactured commodities. The theoretical model applied derives regional comparative advantages in high quality goods from regional differences in factor costs and regional variations in accessibility to R&D activities. These accessibilities are assumed to capture the importance of external knowledge flows from R&D activities within the own regions and in surrounding regions. Consequently, this theoretical framework emphasizes the role of knowledge flows from R&D in generating spatial technology advantages.

The empirical analysis focuses on the influences of human capital input and spatial knowledge flows from R&D activities on the revealed comparative advantages in production of high quality goods. These relationships are examined in a cross-regional setting that also includes an industry dimension. Besides the variables reflecting the input of human capital in a given sector and region, the regression model also includes variables that may detect knowledge and technology transfers from R&D activities in the own locality as well as in other regions, along with variables assumed to
capture any possible knowledge spillovers from multinational firms. The regression model is applied to four different specifications of the dependent variable, revealed comparative advantages, corresponding to four different definitions of high quality products.

The results of the regression analysis show a significant positive impact of human capital inputs on the revealed regional specialization of industries along the range of product quality. The sign and size of the estimated regression coefficient of this variable is robust over the four different specifications of the RCA index. This finding suggests that production of differentiated varieties of all above-average qualities is intensive in human capital. Moreover, the results indicate significant positive effects of knowledge flows from local R&D activities and from R&D efforts in other municipalities within their own functional region. These results are robust for all specifications of the dependent variable in terms of the sign of the estimated coefficients. The size and significance of the regression coefficients increases with the product quality level, which suggests that technological transfers from R&D activities are of larger importance for the most superior levels of product quality. The inter-regional accessibility to R&D, presumed to capture the presence of knowledge flows from locations outside the own functional region, does not show any significant influences on the pattern of spatial specialization in product quality. This empirical finding supports previous empirical evidences of the role of geographical proximity for knowledge spillovers to emerge. These results also conform to empirical results from cross-country analyses, which report weak significance of human capital variables along with relatively strong influences of R&D activities (Faruq, 2006; Ferragin and Pastore, 2005; Martín and Orts, 2001). Furthermore, the presence of multinational firms seems to stimulate the production of high quality goods in Swedish manufacturing in all four segments of product quality considered in this analysis. This result is consistent with previous empirical findings that support the hypothesis of international technology transfers through multinational firms (Faruq, 2006).

In addition to confirming some results from cross-country studies on vertical specialization, this study also identifies spatial knowledge flows as an important factor in explaining spatial patterns of specialization and trade in quality differentiated goods. The intra- and inter-industry/firm linkages that diffuse technological knowledge over space and across sectors are crucial for understanding the fundamental causes of quality competitiveness of firms, regions and nations. How these relationships operate across firms and industries is an important issue for further research.
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Chapter 4:  
Scale and Scope – 
Human capital and the structure of regional export flows

Martin Andersson & Sara Johansson

Abstract

This paper presents an empirical analysis of the influences of human capital endowments on the structure of regional export flows. Since the development of each export product variety may be assumed to be associated with innovation activity, requiring human capital inputs, the core hypothesis tested in this paper is that spatial variations in endowments of human capital influence the extensive margin (number of export products) rather than the intensive margin (average export value per product). The hypothesis is tested in a cross-regional regression model, applied to aggregate and within-industry export flows from Swedish municipalities. The empirical results confirm the theoretical prediction that the response of regional export flows to cross-regional variations in human capital is an increase in the extensive margin. To the extent that human capital endowments affect the intensive margin, the effect is a higher average price per export product.

JEL: F12, F14, R12, R32

Keywords: product differentiation, knowledge, human capital, accessibility, export diversity, extensive margin, economies of scale

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1. Introduction

This paper analyzes the relationship between the structure of export flows from different municipalities (local urban areas) and spatial variations in human capital endowments. The analysis considers how the internal geography of human capital in a country shapes the trade flows to foreign markets from its different locations. The approach of the study may be thought of as an analysis of a country’s export, while taking spatial heterogeneity into account. The national export flow is, indeed, the sum of firms’ export activities and firms are located in different places.

Knowledge is a core variable in many modern theories of international trade and its role for exports and comparative advantages has been emphasized at least since the 1960s by e.g. Posner (1961), Vernon (1966) and Hirsch (1967). According to this view, comparative advantages are dynamic and develop over time as knowledge accumulates, through e.g. investments in and absorption of knowledge and information from different sources. It should be clear that the spatial distribution of human capital – i.e. the knowledge, competencies and skills embodied in people in different locations – influences the spatial pattern of comparative advantages as well as the structure of specialization and trade across regions.

Traditional perspectives in the international trade literature tend to disregard the regional distribution of a country’s export since human- and investment capital are typically assumed to move freely between different locations within a country. This free mobility wipes out factor price differentials and subsequent differences in specialization across regions. Unless for spatially ‘trapped’ factors – like natural resources – the composition of export flows to foreign countries from the different regions of a country should be similar.

Although human capital is essentially mobile, its spatial distribution is highly persistent and invariant over time. One reason is that the choice of spatial location of individuals is largely dependent on individual and regional characteristics, such as educational level, age, regional quality of life factors and local labor market attributes (Feridhanusetyawan and Kilkenny, 1996). Those are regional characteristics that change at a very slow pace. Another reason is that human capital tends to be attracted to places with already high levels of human capital (Berry and Glaeser, 2005). Johansson and Wigren (1996) use the term ‘production milieu’ to denote slowly changing and spatially sticky features of a region that influences
production and specialization opportunities. The human capital in a region is one such feature.

It may be obvious that the geographical distribution of human capital plays a fundamental role in shaping spatial patterns with regard to comparative advantages, specialization and export market performance (cf. Grossman and Helpman 1991b). What is less clear, however, is in what way regional endowments of human capital influence regional export. What components of regional export flows reflect the fact that human capital endowments differ between regions?

This analysis focuses on supply-side influences on export flows and asks the question how export flows from municipalities that are well endowed with human capital differ from export flows from other municipalities. With the objective to analyze this question, the study contributes to the literature in two respects. First, focusing on human capital, it presents empirical evidence of the role of regional supply-side characteristics for understanding the internal geography of a country’s aggregate exports. Second, the paper contributes to the literature on how different margins in trade flows adjust to variations in supply-side factors.

This study follows Hummels and Klenow (2005) who inquire into how large countries export more than small countries by distinguishing between different margins of trade flows. Specifically, we make a distinction between the intensive margin (exports per product) and the extensive margin (number of products). The intensive margin is further divided into one price and one volume component. The empirical analysis is designed to reveal the contribution of each respective margin to the overall relationship between exports and human capital across regions.

Theoretical arguments from the literature of innovation and product life cycles stress that the level of human capital in a region and the potential for knowledge flows should primarily be associated with the extensive margin of trade, i.e. the number of exported product varieties and the average quality of the exported goods. The extensive margin of a region’s aggregate export flow is assumed to reflect the number of product varieties developed by firms located in that region. The development of each such variety can be assumed to be associated with innovation activity requiring human capital inputs. The basic conjecture is that environments with richness and density

27 For aggregate exports, Hummels and Klenow (2005) find that the extensive margin accounts for about 60 percent of the larger exports of larger economies. Within product categories, they show that richer countries export larger volumes at somewhat higher prices.
of human capital are conducive to the arrival of ideas for product varieties (e.g. through knowledge flows). In this way, the stock of product varieties of a region in any point in time reflects the stock of realized ‘innovation ideas’ (cf. Andersson and Johansson 2008). Human-capital abundant regions also provide the necessary accessibility to human capital to realize such ideas. Moreover, high-quality products can readily be assumed to have a larger content of knowledge and human-capital than other products. Therefore, we expect that regions that are well endowed with human capital specialize and export high-quality products. For a given sector in a region, this is assumed to apply to the influence of the human capital employed in the sector and the influence of human capital employed in other sectors. Making use of detailed export data, cross-tabulated on sectors and municipalities, our empirical results confirm both hypotheses.

The remainder of the paper is organized as follows: The next section presents the theoretical background and discusses previous empirical results in related research. Section 3 presents the empirical strategy for analyzing how regional variations in human capital endowment affect the structure of regional export flows. The results of the econometric estimations are presented and discussed in Section 4, followed by a summary of conclusions in Section 5.

2. Human Capital and the Structure of Export Flows

An analysis of how the internal geography of human capital affects the structure of export flows basically relates to three veins in the economic literature, which are briefly reviewed in this section.

2.1 Human capital and export performance

A vast body of theoretical and empirical work emphasizes the role of human capital, R&D and innovation for international competitiveness and export performance at the level of nations, regions as well as firms. Fagerberg (1988), Greenlagh (1990) and Gustavsson et al. (1999) (among others) conclude that technological factors are important for countries’ international competitiveness and trade specialization. Grossman and Helpman (1991b), Fagerberg (1996) and Braunerhjelm and Thulin (2008) show that investments in R&D create comparative advantages in high-tech sectors,
which increase the share of high-tech goods in a country’s aggregate export. Regional studies on R&D and export performance have shown that regional R&D activities amplify diversity of export sectors (Johansson and Karlsson 2007), stimulate regional export specialization in technologically advanced goods (Breschi and Palma, 1999; Gråsjö, 2006) and increases firms’ export market participation (Andersson and Johansson, 2008). At the firm-level, several studies have shown that R&D investments stimulate export market participation and export intensity (Wakelin 1998; Sterlacchini 1999; 2001; Bleaney and Wakelin, 2002; Barrios et al., 2003). Taken together these empirical findings indicate that knowledge and R&D investments have a positive impact on firms’ competitiveness in international markets, which stimulates export market performance in several dimensions. In more explicit terms, previous studies show that knowledge and R&D have a positive effect on export volumes, export prices as well as the size of the export base. However, few studies have analyzed the importance of knowledge and R&D on these three components of export flows simultaneously.

2.2 Product Variety and Human Capital Inputs

Lancaster (1966; 1980) defines products having the same set of characteristics as varieties belonging to the same product group. If varieties in the same product group have different proportions of characteristics but none has a larger amount of every attribute, they are horizontally differentiated. Horizontally differentiated product varieties have similar but not identical attributes, implying that consumers and customers in general perceive such varieties as imperfect substitutes. The existence of many product varieties reflects a demand for variety, either because consumers maximize utility by consuming many differentiated varieties (‘love for variety’) or due to heterogeneity in consumers’ perceptions of which is the ideal composition of product characteristics (most preferred variety). Vertical product differentiation occurs when products differ in quality and, subsequently, also in price (e.g. Flam and Helpman 1987; Falvey and Kierzowski, 1987). Vertical product differentiation is a response of suppliers to heterogeneity among customers as regards preferences for product quality.

Heterogeneous consumer preferences or preferences for variety allow firms to differentiate their products. Differentiation is achieved through investments in innovative activities that result in new combinations of product characteristics embodied in specific varieties. Product varieties may be physically similar but are economically differentiated by the fact that buyers perceive them as imperfect substitutes. As a result, each firm faces its
own separate downward sloping demand curve. Such demand properties provide a possibility for firms to charge a price mark-up over marginal costs i.e. the firm enjoys monopolistic ascendancy on its market.

It is generally recognized that product differentiation induces a fixed investment or fixed production cost, which makes mark-up pricing a necessity to avoid negative profits. Provided that the number of suppliers and product varieties in the commodity group is sufficiently large, it is rational for each firm to take the behavior of other firms as given. If, in addition, there is free entry and exit of firms, product differentiation is consistent with monopolistically competitive market equilibrium where net profits are squeezed to zero. A market structure characterized by monopolistic competition was first analyzed by Chamberlin (1933), who argued that the monopolistic feature of the market is deduced from the elements that distinguish product varieties from one another and give firms a limited market power. The large number of operating firms and the possibility of free entry and exit constitute, on the other hand, the competitive elements in this market structure.

The implications of demand structures reflecting preferences for variety and market structures characterized by monopolistic competition on trade patterns were formalized in a seminal paper by Krugman (1980). Based on assumptions of product differentiation, monopolistic competition and increasing returns to scale, Krugman's theoretical model is a natural point of departure in analyzing the influences of human capital on regional export structures. This is because the production of differentiated goods can readily be assumed to require a fixed input of human capital associated with research and product development, development of brand profiles, marketing etc, which insulates the demand for the firm's output from actions undertaken by its competitors. That input of human capital is a prerequisite for both horizontal and vertical product differentiation has been showed in a number of empirical studies during the last decades (Chiarlone, 2000; Martin and Orts, 2001; Ferragin and Pastore, 2005; Faruq, 2006; Johansson, 2008).
2.3 Regional Endowments of Human Capital and Knowledge Flows

It is well documented that knowledge in the form of human capital, R&D activities or in other measures tend to be strongly concentrated in space (Audretsch and Feldman 1996). Density of firms and human capital is assumed to bring advantages pertaining to the spread of ideas, knowledge and innovation (Glaeser 1994; Feldman 1999). The localized nature of knowledge spillovers suggests that knowledge accumulation is faster in regional environments with high knowledge density. This reasoning also applies specifically to human capital. Following the arguments outlined in Lucas (1988), there is a large empirical literature focusing explicitly on so-called ‘human capital externalities’ in dense environments with concentrations of educated people (e.g. Rauch 1993; Moretti 2004). The regional perspective on human capital and exports should be appreciated in this context.

Johansson and Wigren (1996) suggest that the level of human capital in a region can be described as a property of its production milieu. The production milieu comprises slowly changing and spatially trapped features, which have an influence on the production and specialization possibilities of the firms in the region. Human capital can be thought of as the specific knowledge that each worker possesses. This specific knowledge can be of either technical or entrepreneurial nature and is characterized by the particular feature that it is non-rivalrous. Non-rivalry is a feature of a pure public good (Romer 1990). Nevertheless, for certain types of knowledge it is possible to exclude other economic agents from using it commercially by means of patents and trademarks. Thus, not all knowledge is a pure public good in the sense that anyone can freely use it for whatever purpose one wants. Still, even if excludability prevails as regards commercial use, the actual knowledge can be used in the generation of new knowledge applications. This implies that knowledge to some extent is a public good that can spill over between economic agents. An appropriate definition of regional human capital endowment must, consequently, include external knowledge flows in such a way that spatial knowledge spillovers augment the regional human capital endowments.

28It is frequently claimed that the continued spatial concentration and clustering of economic activities, despite lower transportation costs and ICT, should partly be understood as a response to an increased role of knowledge, innovation and technology in the economy. Many scholars argue that spatial transactions costs for routinized and standardized activities have fallen, whereas they have increased for knowledge-intensive and non-routine activities (McCann 2008; Glaeser and Kolhase 2004). Hence the tendency of ‘knowledge’ to cluster spatially.
As argued by Acs et al. (2008) and Federici et al. (2008), the kind of knowledge crucial for entrepreneurship and innovation tends to be tacit or sticky in the sense that it is not codified. Such tacit knowledge is an individual asset, based on personal experiences and interactions. This tacit knowledge is mainly exchanged through interpersonal contacts, such as face-to-face business communications, business collaboration, seminars, fairs, etc. Because of travelling costs in terms of time and money, the frequency of these kinds of face-to-face communications decreases with the time distance between the agents involved (Pred 1966; Feldman 1994). Thus, the transmission and absorption of knowledge is facilitated by geographical proximity. Indeed, a large number of empirical studies in the last 15 years indicate that knowledge flows are bounded in geographical space.

3. Empirical Strategy

From the arguments presented in the previous section pertaining to (i) horizontal and vertical product differentiation, which require investments in knowledge and (ii) regional endowment of human capital as a source of external knowledge flows, we derive three hypotheses that we aim to test:

- The predominant effect of regional variations in human capital endowment on regional export flows is regional variability in the extensive margin of these flows, i.e. the number of export products.
- The price component of the intensive margin is positively related to the regional endowment of human capital.
- Since the regional abundance of human capital provides a source for spatial knowledge spillovers, it is expected that such external knowledge flows have a positive effect on the extensive margin and the price component of the intensive margin.

We test these hypotheses with data on exports of manufactured goods from Sweden’s 288 municipalities in the year 2003. The municipality data is aggregated from firm-level data, containing information about export value and export volume for each firm at the 8-digit level of product classification according to the combined nomenclature (CN). We regard each firm-level observation in each 8-digit product group as a unique product variety. Each firm is thus assumed to produce a distinct variety. We may think of an 8-digit code as a product group, and the number of firms with positive exports of that product group as the number of varieties. The number of varieties is,
accordingly, given by the number of ‘firm-product-group-specific’ observations in each municipality. Firms, and their products, are also classified to a 2-digit industry. Aggregation of firm- and product-specific observations to the level of 2-digit industries and municipalities results in a data set containing 3788 industry-location-specific observations. Human capital is approximated by the amount of workers with at least three years of university education employed in each region and sector.

To test the hypothesis that spatial variations in endowment of human capital mainly affect the extensive margin of export flows from different municipalities, we begin with applying a cross-regional regression model of the form:

$$\ln V_s = \alpha + \lambda_1 \ln emp_s + \lambda_2 \ln H_s + \eta_s$$

where $V_s$ is the aggregate export value of municipality $s$, $emp_s$ is the total employment in $s$ which reflects the size of the municipality, and $H_s$ is the endowment of human capital. $\eta_s$ is the error term subject to the usual assumption of a zero mean and normal distribution.

How do we define spatial endowment of human capital? The approach taken here is to consider a municipality’s total accessibility to educated workers. For a given municipality, such a measure accounts for the human capital in each and every municipality and discounts the human capital in other municipalities with a distance decay function. The total endowment of human capital in municipality $s$ is given by:

$$H_s = S_s f(c_s) + S_1 f(c_{s1}) + S_2 f(c_{s2}) + \ldots + S_n f(c_{sn})$$

where $S_s$ is the number of educated workers employed in municipality $s$ and $f(c)$ is a distance decay function that determines how the accessibility value is related to the cost of spatial interaction. A common approximation of this distance decay function is an exponential function (Weibull 1976):

$$f(c) = \exp\{-\alpha c\}$$

where $c_{sr}$ is the travel-time distance by car between municipality $s$ and $r$ and $\alpha$ is a pre-estimated time-sensitivity parameter, reflecting the sensitivity of
the accessibility to changes in travel time distances\textsuperscript{29}. Combining Equations (2) and (3), the human capital endowment of municipality $s$ is defined as:

$$H_s = \sum_{r,s} S_r \exp\{-\sigma_{rs}\}$$

Equation (4) expresses the accessible human capital of municipality $s$ as the sum of its internal and external educated labor, weighted by a spatial discounting matrix\textsuperscript{30}. This accessibility depicts the total amount of human capital that is potentially available to any firm in municipality $s$\textsuperscript{31}. This measure also reflects potential external knowledge flows that may influence firms and is, therefore, an appropriate measure of the municipality’s human capital endowments. This way of measuring spatial abundance of human capital implies that variations in human capital across locations can arise solely from differences in the internal and external geography of knowledge.

In order to disentangle which margins of regional trade flows that are affected by variations in regional human capital endowments, we note that the export flows of a region consist of three separable components:

i. the number of product varieties exported
ii. the average export price per product variety
iii. the average quantity exported per product variety

Variations in the size of regional export flows can be due to variations in any of these three components. We break down the aggregate export flow from a given industry and region into the three components:

$$V = n \bar{q} \bar{p}$$

where $V$ denotes total export value, $n$ is the number of product varieties exported and $\bar{q}$ and $\bar{p}$ denote the average export quantity and the average export price, respectively. In logarithmic form this relationship is written as:

$$\ln V = \ln n + \ln \bar{p} + \ln \bar{q}$$

\textsuperscript{29} See Johansson, Klaesson and Olsson (2002; 2003) for a thorough analysis of time sensitivities in travels.

\textsuperscript{30} For a formal definition of accessibility, see for example Gräsjö (2006)

\textsuperscript{31} A measure of accessibility should satisfy certain criteria of consistency and meaningfulness, the measure used here satisfies those warranted criteria as shown by Weibull (1976).
where $\ln n$ is the extensive margin of the aggregate export flow and $\ln p + \ln q$ constitutes the intensive margin, consisting of the average price per exported unit and the average quantity exported per product. With these notations, the model in Equation (1) can be regressed on each variable in Equation (6) for the purpose of analyzing the influences of regional human capital endowments on the extensive respectively the intensive margin and the price, respectively, the quantity component.

While we estimate the described model for aggregate regional export flows, we recognize that there are large variations in knowledge intensity across sectors and this industry heterogeneity may generate an endogeneity problem since the actual employment of educated labor in a location depends on the demand for human capital in that location’s manufacturing sector. Furthermore, the possibility to differentiate products and the demand for product variety differ across industries and product groups. Consequently, the observed amount of educated and unskilled labor in regional employment is likely to be a result of the industrial structure of the region.

In order to preclude empirical results generated by regional variations in industrial structure rather than by regional variations in human capital endowments, we also perform a regression analysis that includes an industry dimension. For this purpose, we formulate a regression model that allows us to analyze within-industry variation in the size and structure of export flows across municipalities. In this model, cross-regional variations within industries in terms of export value are explained by (i) the employment of educated and unskilled labor in that sector and municipality, (ii) the accessibility to educated labor in other sectors in the own municipality and (iii) the accessibility to educated workers in all sectors in all other municipalities (Figure 4.1).
Figure 4.1. Structure of the empirical model for within-industry differences in regional exports and human capital

As shown in Figure 4.1, we separate between internal human capital (educated labor employed in the local industry) and external human capital (educated labor employed in other industries and/or in other municipalities) in the region-industry-model. A logarithmic form of this model, including industry specific dummy variables to control for unobserved industry heterogeneity, is formulated as:

\[
\ln V_{j,s} = \ln L_{j,s} + \ln S_{j,s} + \sum_{i \neq j} \ln \left( f(c_{si}) \sum_{i \neq j} S_{i,s} \right) + \ldots + \gamma_4 \ln \left( \sum_{i \neq j} \left( f(c_{wi}) \sum_{i \neq j} S_{i,s} \right) \right) + \gamma_5 D_j + \varepsilon_{j,s}
\]

(7)

where \( L_{j,s} \) is the number of unskilled labor employed in industry \( j \) in municipality \( s \) and variations in the human capital input across municipalities and sectors are reflected by the variable \( S_{j,s} \). The influence of spatial knowledge flows within the municipality is captured by the term \( \sum_{i \neq j} S_{i,s} \), which is the local accessibility of industry \( j \) in municipality \( s \) to educated labor employed by other sectors in municipality \( s \). The model also includes a variable reflecting knowledge flows from other
municipalities, \(\sum_{r \neq s} \left( f(c_{r,s}) \sum_{j \neq r} S_{j,s} \right)\), which is the accessibility of any industry in region \(s\) to educated persons employed in all other municipalities. Unobserved industry heterogeneity, originating from differences in knowledge intensity, minimum efficient production scale, transport costs, trade costs and so on, is controlled for by a vector of industry-specific dummy variables, \(D_j\). Finally, \(v\) is the intercept term and \(\epsilon_{j,s}\) is an error term assumed to have zero mean and to follow a normal distribution.

Due to large variations in the size of Swedish regions in terms of population and employment, all components of regional export flows tend to have a skewed distribution. Table A1 in Appendix displays descriptive statistics for the dependent variables considered in the econometric estimations. Each of these variables (except the average export quantity) has a mean value that by far exceeds the value of the median observation, which indicates a positively skewed distribution (negatively skewed in the case of average export quantity). The implication of this is that the residuals from OLS estimations of the regression model in Equation 3.1 and Equation 3.4 do not fulfill the assumption of homoscedasticity. To produce efficient estimates of the regression coefficients, the regressions are estimated by means of FGLS, using White’s robust covariance matrix. The results of these estimations are presented in Section 4.

Another consequence of the skewed distributions of the dependent variables is that the marginal effects of the explanatory variables may vary along the distribution of the dependent variable. Since OLS and GLS estimate the conditional mean of the dependent variable as a function of the explanatory variables, these estimation methods cannot account for the possibility that the estimated effects of the covariates differ between different points on the conditional distribution of the dependent variable. In this case, quantile regression techniques offer a solution as it enables the estimation of any conditional quantile of the dependent variable as a function of the independent variables. Koenker and Basset (1978) originally proposed quantile regressions as an alternative to OLS when residuals are not normally distributed. However, since marginal effects are the same across all quantiles of the dependent variable only in the special case where the errors are homoscedastic, the quantile regression estimator also particularly useful in the presence of heteroscedasticity (Gräsjö, 2006).

With the intention to present a more complete picture of the influences of knowledge on the structure of regional export flows, the FGLS estimations of the regression model in Equation (7) is complemented with quantile
regressions for the 25th quantile, the median quantile and the 75th quantile. Analogously to a standard OLS regression, which estimates the conditional mean of a random variable, the quantile regression model expresses the conditional quantile of the dependent variable as a linear function of some independent variables. For the \( \theta \)th quantile \((0 < \theta < 1)\) the regression model is expressed as:

\[
v_{j,s} = X_{j,s}' \beta_\theta + \mu_{\theta,j,s}
\]

where \( \beta_\theta \) is the unknown vector of regression parameters associated with the \( \theta \)th quantile and \( X_{j,s} \) is a vector containing the same independent variables as the regression model in Equation (7) and \( \mu_{\theta,j,s} \) is the error term. The \( \theta \)th quantile of \( v_{j,s} \) given \( x_{j,s} \) is \( Q_\theta(v_{j,s}|x_{j,s}) \). The quantile regression estimate of \( \beta_\theta \) is the value of \( \beta_\theta \) that minimizes the sum of the absolute deviations residuals:

\[
\min_{\beta} \frac{1}{n} \left( \sum_{v_{j,s} > x_{j,s} \beta} |v_{j,s} - x_{j,s}' \beta| + \sum_{v_{j,s} < x_{j,s} \beta} |v_{j,s} - x_{j,s}' \beta|(1-\theta) \right)
\]

According to Equation (9) the regression coefficients of different quantiles are estimated with different weights given to the residuals. For the median regression, all residuals receive equal weight, whereas negative residuals are given a weight of 0.25 and positive residuals a weight of 0.75 when estimating the 75th percentile. Moreover, Gould (1992) and Gråsjö (2006) suggest a bootstrap re-sampling procedure for estimating standard errors in data sets with heteroscedastic error distributions. This procedure is preferable since it only affects the standard errors and associated significance levels while leaving the estimations of quantile regression coefficients unchanged. Accordingly, the standard errors in the quantile regressions are obtained by bootstrapping the entire vector of observations. The results of these estimations are presented in the next section.

4. Results

The theoretical argument that the process of horizontal product differentiation depends on the input of human capital implies that regional variations in human capital endowment are expected to affect the number of
varieties exported rather than the volume exported of each variety. Moreover, vertical product differentiation results in product varieties with different amount of knowledge content. Consequently, spatial variations in the endowment of human capital are expected to affect the unit price of export products rather than the quantity exported. These hypotheses are tested by FGLS estimations of the cross-regional regression model presented in Equation (1) and FGLS estimations of the two-dimensional regression model presented in Equation (7). These models are regressed on five different dependent variables: total export value, extensive margin (number of export products), the intensive margin, the average export price and average export quantity. Thereafter, the robustness of the regression coefficients produced by FGLS estimations across different points on the conditional distribution of the dependent variables is examined by estimation of quantile regressions.

The results of FGLS estimations of the cross-regional regression model, displayed in Table 4.1, show that the aggregate export flow from a municipality is increasing with both municipality size (in terms of employment) and with the endowment of human capital (measured by accessibility to human capital). The values of the estimated coefficients for the extensive and intensive margins (column 2 and 3) additively sum to the regression coefficients for the aggregate export value (column 1). Accordingly, the coefficients in Table 4.1 indicate that 82 % (0.983/1.202) of the total effect of spatial variations in employment falls on the extensive margin of export flows. In accordance with the findings presented by Hummels and Klenow (2005), these results show that the major explanation for the larger export flows from large municipalities is that the number of export products increases with the size of the municipality. Furthermore, the regional endowment of human capital affects the extensive margin only, whereas the effect of this variable on the intensive margin is negative, yet not significant.

The intensive margin can be divided into a price and a quantity component. Column 4 and 5 in Table 4.1 show that municipality size has a negative influence of the average price of the exported products, whereas there is a significant positive influence of municipality size on the average quantity exported per product. The average export price is positively related to the endowment of human capital, whereas the average export quantity is decreasing with the municipality’s endowment of human capital. In summary, these results indicate that the export flows from human capital abundant municipalities are more diversified and consists of goods with a relatively high unit value. These findings are consistent with the results from cross-country data presented by Hummels and Klenow (2005) and support
theoretical trade models based on product differentiation and monopolistic competition (Krugman 1980). Moreover, these results support the theoretical conjecture of a positive effect of human capital on the extensive margin and a positive effect on the price component of the intensive margin in aggregate export flows from different municipalities.

Table 4.1 Results of cross-regional regression estimations

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Aggregate export value</th>
<th>Extensive Margin</th>
<th>Intensive Margin</th>
<th>Average export price</th>
<th>Average export quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipality size (total employment)</td>
<td>1.202**</td>
<td>0.983**</td>
<td>0.219*</td>
<td>-0.153*</td>
<td>0.372**</td>
</tr>
<tr>
<td>(0.106)</td>
<td>(0.015)</td>
<td>(0.089)</td>
<td>(0.078)</td>
<td>(0.138)</td>
<td></td>
</tr>
<tr>
<td>Human capital endowment (Total accessibility to human capital)</td>
<td>0.201*</td>
<td>0.250**</td>
<td>-0.044</td>
<td>0.253**</td>
<td>-0.297*</td>
</tr>
<tr>
<td>(0.100)</td>
<td>(0.005)</td>
<td>(0.079)</td>
<td>(0.073)</td>
<td>(0.132)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>7.800***</td>
<td>-5.213**</td>
<td>13.036**</td>
<td>2.337**</td>
<td>10.677**</td>
</tr>
<tr>
<td>(0.881)</td>
<td>(0.129)</td>
<td>(0.731)</td>
<td>(0.656)</td>
<td>(1.145)</td>
<td></td>
</tr>
<tr>
<td>R²-value</td>
<td>0.52</td>
<td>0.78</td>
<td>0.03</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>Number of observations</td>
<td>288</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses. **Significant at the 1% level. *Significant at the 5% level

As discussed in the previous section, however, the results of the cross-regional regression model may be driven by regional differences in industry structures. To control for spatial heterogeneity in industry structure, we analyze within-industry variations of export flows across municipalities through FGLS estimation of the two-dimensional regression model specified in Equation 3.4. The results of these estimations are displayed in Table 4.2.

The figures in the first column of Table 4.2 show that the total export value is positively affected by all variables included in the model and the regression coefficients are strongly significant. Columns 2 and 3 reveal that the input of unskilled labor has a positive effect on both the extensive and intensive margin, yet the size of the estimated coefficient for the intensive margin is about three times larger than the estimated coefficient for the
extensive margin. Hence, spatial variations in the size of industries (measured as the input of unskilled workers) predominantly affect the intensive margin of export flows. In fact, 73 % (0.617 / 0.850) of the variations in aggregate export flows due to differences in the input of unskilled labor across industries and municipalities are explained by variations in the intensive margin. Only 27 % (0.233 / 0.850) of the effect of variations in employment of unskilled labor is attributed to variations in the extensive margin. Columns 4 and 5 show that it is the quantity component of the intensive margin that is positively affected by the input of unskilled labor, whereas this variable has a significant negative effect on the price component. This outcome indicates that cross-regional differences in input of unskilled labor within industries result in an adjustment of the intensive margin of export flows.

The figures presented in the second row in Table 4.2 reveal that cross-regional differences in the employment of skilled workers within industries mainly influence the intensive margin and only about one third (35 %) of the effect of human capital input falls on the extensive margin. The coefficients in columns 4 and 5 indicate that the predominant effect of variations in human capital input on the intensive margin is an adjustment of the quantity component. The effect on the price component of the intensive margin is positive but smaller and not significant.

The results from the regression estimations presented in Table 4.2 indicate that when cross-industry heterogeneity, such as average knowledge intensity and average production scale, are controlled for by the inclusion of industry dummy variables, the predominant effect of spatial differences in sector size and human capital input is an adjustment of the intensive margin in export flows.

However, the employment of educated labor in each industry and region does not necessarily capture all the knowledge that is actually used in the development and production of differentiated varieties. Each sector may benefit from external human capital as educated workers in other sectors and in other locations can be used in development or production processes, either through business transactions or through pure knowledge spillover effects. In either case, the geographical accessibility to educated workers is likely to reflect the potential of a sector in a given location to benefit from the human capital employed in other locations and other sectors. In accordance with theoretical predictions, the local accessibility to educated workers in other sectors show a positive and strongly significant impact on the total export value of industry \( j \) in municipality \( s \). Interestingly, more than 100 percent of this effect falls on the extensive margin, whereas the intensive margin is
negatively influenced by knowledge flows from other sectors in the municipality. Furthermore, columns 4 and 5 in Table 4.2 show that the local accessibility to educated workers in other sectors has a positive effect on the average export price and a negative effect on the average export quantity. This result suggests that industries located in places where human capital is abundant specialize in commodities of higher values and operate on a smaller production scale. This is consistent with standard spatial product cycle models where innovation activities in early phases of the product cycle are located in regions rich in human capital and other ‘innovation inputs’, but the production of more standardized goods in later stages of the cycle exploit internal scale economies and locate in regions with low costs of labor and land.

The results presented in Tables 4.1 and 4.2 support the theoretical expectations that the municipality’s endowment of human capital, measured as accessibility to educated labor, enhances the capacities of innovation and product differentiation in the municipality’s export sector. This product differentiation results in smaller export volumes per product, whereas the average export price is higher than in municipalities that are poorly endowed with human capital. The results in Table 4.2 also indicate that the accessibility to human capital in other municipalities has a positive effect on both the extensive and intensive margin of export flows. A closer examination of the intensive margin shows that municipalities with a high accessibility to human capital in other municipalities export goods at larger volumes. This result suggests that knowledge flows that are less spatially localized augment regional export production possibilities, both in terms of the number of export varieties and in terms of the average size of export volumes, but has no significant effect on average unit values. This finding indicates that municipalities with low internal accessibility to human capital specialize in goods of low unit values exported in large volumes. This may be the only option when proximity to human capital is very small. Still, such locations seem to benefit from knowledge flows from other regions in expanding their export bases.
### Table 4.2 Results of two-dimensional regression estimations

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Aggregate export value</th>
<th>Extensive Margin</th>
<th>Intensive Margin</th>
<th>Average export price</th>
<th>Average export quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employment of unskilled labor in industry (j) in municipality (s)</strong></td>
<td>0.850** (0.037)</td>
<td>0.233** (0.015)</td>
<td>0.617** (0.030)</td>
<td>-0.095** (0.021)</td>
<td>0.712** (0.038)</td>
</tr>
<tr>
<td><strong>Employment of educated workers in industry (j) in municipality (s)</strong></td>
<td>0.052** (0.012)</td>
<td>0.018** (0.005)</td>
<td>0.034** (0.009)</td>
<td>0.010 (0.007)</td>
<td>0.024** (0.012)</td>
</tr>
<tr>
<td><strong>Local accessibility to educated workers in other sectors in municipality (s)</strong></td>
<td>0.439** (0.030)</td>
<td>0.507** (0.012)</td>
<td>-0.067** (0.025)</td>
<td>0.019* (0.009)</td>
<td>-0.087** (0.032)</td>
</tr>
<tr>
<td><strong>Accessibility to educated workers in all sectors and all locations outside municipality (s)</strong></td>
<td>0.210** (0.024)</td>
<td>0.111** (0.009)</td>
<td>0.099* (0.020)</td>
<td>0.001 (0.016)</td>
<td>0.098** (0.028)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>7.211** (0.310)</td>
<td>-2.239** (0.129)</td>
<td>9.450** (0.248)</td>
<td>4.672** (0.175)</td>
<td>4.778** (0.317)</td>
</tr>
</tbody>
</table>

| \(R^2\)-value | 0.53 | 0.64 | 0.42 | 0.48 | 0.48 |

| Number of observations: | 3788 |

Robust standard errors in parentheses. ** Significant at the 1% level. *Significant at the 5% level.

In summary, the results presented in Table 4.2 reveal that the extensive margin of a sector’s export flow is growing with the accessibility to human capital in other sectors and municipalities. This outcome suggests that a substantial fraction of the innovation and development activities that generate differentiated products takes place outside their own sector or outside their own municipality. As a consequence, industries in locations that are well endowed with human capital have a more diversified export, consisting of product varieties of relatively high value.

The regression model applied on the data set cross-tabulated on industries and municipalities performs fairly well in estimating variations in export...
flows across industries and regions. When regressing the model on the total export value, the model explains 53% of the variations in the size of aggregate export flows across industries and regions. The R-square value is highest in the regression where the extensive margin is the dependent variable (0.65) and lowest in the regression where the intensive margin is the dependent variable (0.42). The regression model applied on the two-dimensional data set has a substantially higher power in explaining adjustments in the intensive margin than has the regression model that only includes a spatial dimension.

Addressing the issue of variations in estimated effects along the distribution of the dependent variable, Table 4.3 presents the results of quantile regressions estimated for the three components in aggregate export flows: the number of export products, average export price and average export quantity. For each one of these three dependent variables, regressions are estimated for the 25th quantile, the median quantile and the 75th quantile.

Table 4.3 shows that the sign of the estimated coefficients of all explanatory variables are the same as in the FGLS estimations for the 25th and median quantile in all regressions. For the 75th quantile, the estimated effects have the same sign as in the FGLS estimations in all regressions except for the specification where average export price is the dependent variable. In contrast to the FGLS estimations, the impact of internal and external accessibility to educated workers appear to have a negative effect on the average export price in the 75th conditional quantile of this dependent variable. However, these coefficients are not statistically significant.

Another observation from Table 4.3 is that the size of the estimated coefficients for input of unskilled and educated labor is fairly robust across different quantiles of the dependent variables, whereas the influence of local human capital accessibility seems to be significantly smaller for the upper quantiles of the distribution of number of export products and average export price respectively. In the regression where average export quantity is the dependent variable, the estimated negative effect of local human capital intensity is significantly larger in the 75th quantile.

Summarizing the outcomes of the quantile regressions, we find that the estimated coefficients are generally higher for observations in the median or bottom range of the conditional distribution of the dependent variables. This pattern is particularly distinct for the local accessibility variable, where the confidence intervals indicate a significant difference in the size of the marginal effects between the 25th and 75th conditional quantiles of each one of the dependent variables. These results signify that local knowledge flows
across sectors are particularly important in stimulating growth in the extensive margin in regions where the within-industry regional export flows have relatively low product diversity. The same reasoning applies to the price component in the intensive margins; local knowledge flows across sectors have a larger influence on the average export price in municipalities where the export of a given industry has a relatively low average unit value.
Table 4.3 Results of quantile regressions

<table>
<thead>
<tr>
<th></th>
<th>Number of export products</th>
<th>Average export price</th>
<th>Average export quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q25</td>
<td>Q50</td>
<td>Q75</td>
</tr>
<tr>
<td>Employment of unskilled workers in industry $j$ in municipality $s$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>0.237***</td>
<td>0.235**</td>
<td>0.222**</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.019)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Employment of educated workers in industry $j$ in municipality $s$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>0.019***</td>
<td>0.018**</td>
<td>0.013*</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>Local accessibility to skilled workers in other sectors in municipality $s$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>0.553***</td>
<td>0.496**</td>
<td>0.488***</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.015)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>Accessibility to skilled workers in all sectors and locations outside municipality $s$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>0.134***</td>
<td>0.134**</td>
<td>0.118**</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>-2.370***</td>
<td>-1.425***</td>
<td>3.741**</td>
</tr>
<tr>
<td></td>
<td>(0.144)</td>
<td>(0.165)</td>
<td>(0.211)</td>
</tr>
<tr>
<td>Number of observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>3788</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Robust standard errors in parentheses. ** Significant at the 1% level. * Significant at the 5% level
5. **Summary and Conclusions**

Larger municipalities that are well endowed human capital are expected to have larger export flows. In this paper we ask: *how do they export more?* Previous research has analyzed this question with regard to the exports of countries with different size. This analysis examines the contribution of the different components, i.e. the intensive and extensive margin, of exports across municipalities in Sweden. Instead of focusing on how the different components of export flows vary with sheer size, however, our analysis focuses on how they vary with spatial variations in endowment of human capital, including the potential for spatial knowledge flows. The basic hypothesis is that the extensive margin is driven by innovative efforts and these efforts require human capital. Regions rich in human capital are therefore better equipped for the production of differentiated products.

At the aggregate level our analysis yields the following results:

- Larger municipalities have larger export flows. The elasticity of export flows with respect to a plain size variable (total employment) can be attributed to both the intensive and the extensive margin. Exports prices are negatively related to municipality size, whereas export quantities are positively related to the size variable.

- In line with our expectations, the elasticity of export flows with respect to accessibility to human capital is solely due to adjustments on the extensive margin. Also, average unit prices of exported product varieties are higher in municipalities with higher accessibility to human capital.

These results at the aggregate level can reflect different industry structures in different regions, e.g. human capital intensive regions can be more specialized in sectors characterized by differentiated products as well as differences within industries across regions. Our within-industry analyses show that industries in regions that are well endowed with human capital have a more diversified export flows, consisting of goods of relatively high unit value. They also show that human capital employed in other sectors correlate significantly with the extensive margin and export prices in given sectors.

With these findings, this paper contributes to the literature in two major respects. First, focusing on human capital, it presents empirical evidence of
the role of regional supply-side characteristics for understanding the internal geography of a country’s aggregate exports. Second, the paper contributes to the literature on how different margins of trade adjust to supply-side factors. Specifically, the paper addresses how endowments of human capital influence trade flows.

In relation to previous research this paper has shown that the relationship between exports and human capital at the regional level goes beyond specialization patterns, as indicated by e.g. RCA indices, and also comprise variations in the extensive and intensive margins, as well as prices and quantities. They show that the structure of a region’s export flows is highly related to its ‘production milieu’ in terms of accessibility to human capital. The ability of industries to differentiate their products (horizontally and vertically) and achieve the associated competitive advantages from such differentiation appears to be strongly related to the accessibility to human capital in other sectors in their own region. How the co-location of different economic activities stimulates the arrival of new products and the expansions of regional export bases is an important issue for further research.
References

Chamberlin E. H. (1933) The Theory of Monopolistic Competition. Harvard University Press; Cambridge, Massachusetts
Ejermo, O. (2004) *Perspectives on Regional and Industrial Dynamics of Innovation*, JIBS Dissertation Series; No. 024; Jönköping


Appendix

Table A1 Descriptive statistics of dependent variables

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate export value</td>
<td>10.00</td>
<td>65962590</td>
<td>7635</td>
<td>200151</td>
<td>1731725</td>
<td>28.38</td>
</tr>
<tr>
<td>(thousands SEK)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of export products</td>
<td>1.00</td>
<td>3342</td>
<td>18</td>
<td>57</td>
<td>178</td>
<td>10.43</td>
</tr>
<tr>
<td>Average export price</td>
<td>0.10</td>
<td>30088</td>
<td>73</td>
<td>331</td>
<td>1178</td>
<td>11.88</td>
</tr>
<tr>
<td>(SEK)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average export quantity</td>
<td>1.00</td>
<td>121924</td>
<td>3885</td>
<td>409</td>
<td>3563</td>
<td>20.73</td>
</tr>
<tr>
<td>(tonnes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table A2 Descriptive statistics of independent variables

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
<th>Median</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment of unskilled labor</td>
<td>1.00</td>
<td>17114</td>
<td>44.00</td>
<td>168.70</td>
<td>489.88</td>
</tr>
<tr>
<td>in industry j in municipality s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment of educated workers</td>
<td>0.00</td>
<td>5924</td>
<td>2.00</td>
<td>20.62</td>
<td>155.71</td>
</tr>
<tr>
<td>in industry j in municipality s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local accessibility to educated</td>
<td>24.86</td>
<td>123861</td>
<td>721.12</td>
<td>2834.84</td>
<td>10181.78</td>
</tr>
<tr>
<td>workers in other sectors in municipality s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility to skilled workers in</td>
<td>0.02</td>
<td>87766</td>
<td>4423.60</td>
<td>9485.18</td>
<td>14210.52</td>
</tr>
<tr>
<td>all sectors and locations outside</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>municipality s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5:
Market experiences and export decisions in heterogeneous firms

Sara Johansson

Abstract

This empirical analysis focuses on the impact of firms’ export experiences, other firm characteristics and location-specific variables on export decisions in Swedish manufacturing firms. Three choices of export market participation are considered: permanent export, occasional export and no export. The paper also analyzes firms’ choice of expanding export activities. The empirical results indicate that firm-level variables such as size, human capital intensity and labor productivity increase the probability of a firm being a permanent exporter rather than an occasional or non-exporter. Moreover, firms located in regions with a high concentration of other firms that export commodities in the same product group have a higher probability of both permanent and occasional export market participation. The results also show a significant positive effect of firms’ export experiences in the previous period on the probability that a firm becomes a permanent exporter in the current period. The analysis of export market expansion suggest that firms with high human capital intensity and experiences from exporting several products to several markets are more likely to introduce a new export product. The probability of expanding to new geographical markets seems to be increasing with firm-level labor productivity and export experiences from multiple markets in previous periods.

Keywords: export behavior, firm heterogeneity, learning-by-exporting, experiential knowledge, knowledge spillover, agglomeration economies

JEL: F14

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I. Introduction

In the process of globalization of production and trade more and more firms enter foreign markets to explore business opportunities abroad and to compensate for shrinking domestic sales in face of growing import competition. Despite many push and pull factors, however, many firms do not participate in international markets, and the majority of firms that do, export only few products to a limited number of destinations (Andersson et al. 2007; Bernard et al. 2007). The fact that not all firms exploit business opportunities in foreign markets can be explained by a fixed investment required to establish an export link. A growing vein of theoretical and empirical literature focuses on the effects of fixed export market entry costs on firms’ export behavior. Theoretical and empirical work in this field suggest that only the most productive firms can overcome the fixed cost of export market entry. According to this view, the best firms self-select into export market participation.

Previous studies of firms export behavior find that firm characteristics such as size, productivity, human capital, R&D investments and age are important predictors of a firm’s export status at a given point in time (Bernard and Jensen, 1995, 1999, 2004; Baldwin and Gu, 2003; Clerides et al. 1998; Roberts and Tybout, 1997). Moreover, several studies show that firms’ export status display a significant persistence from one year to another (Roberts and Tybout, 1997; Bernard and Jensen, 2004; Esteve-Pérez, 2006). These findings are consistent with theoretical models by Dixit (1989) and Krugman (1989) proposing that the existence of sunk costs leads to persistence in firms’ export behavior. Still, Bernard and Jensen (2004), Esteve-Pérez (2006) and Alvarez (2007) show that a substantial fraction of firms are not exporting on a permanent basis but enter, exit and re-enter on export markets from year to year. Alvarez (2007) finds significant productivity differences between firms that export occasionally and firms that are permanent exporters. Alvarez (2007) also finds a significant influence of previous export experience on the probability of becoming a permanent exporter. These empirical results suggest that there is a difference in export strategy between permanent exporters and occasional exporters and that firms’ previous export experiences may be decisive for successful export market participation. The purpose of this paper is to explore these issues further.

---

The first objective of this analysis is to examine if decisions about export market participation in Swedish firms are influenced by the same factors as those determining export behavior of firms in other countries. On average, Swedish manufacturers are more export oriented than manufacturing firms in most other countries\textsuperscript{33} and previous studies indicate that productivity levels have smaller impact on firms’ export decisions in countries where the export market participation rate is comparably high (ISGEP, 2008). A high export market participation rate is likely to be an indication of a relatively low export market entry cost. In this case, the productivity threshold for export market participation is low and productivity differences between exporters and non-exporters are, accordingly, small. Cross-country differences in export market participation rates can also be explained by differences in the size of the domestic market. If the domestic market is very small a major share of all firms has to sell their products also in foreign markets in order to reach the minimum efficient scale of production. Moreover, scale economies imply that small economies have to be open to import. A result of the open trade regimes and the high propensity of firms to participate in international markets that generally characterize small economies may be a reduction in the cost of entering foreign markets. This reduction in entry cost may be due to institutional factors (low trade barriers) or due to external flows of knowledge and information about foreign markets across firms. Of particular interest in this context, are the studies by Greenaway et al. (2005) and ISGEP (2008) that find no significant productivity differences between exporters and non-exporters in Sweden. However, these studies make no distinction between permanent and occasional exporters and the first aim of this paper is to analyze if differences in firm-level productivity can explain the choice of permanent, occasional or no export activity in Swedish manufacturing firms.

The high degree of export market participation among Swedish firms highlights the potential for knowledge and information spillovers from and across exporting firms. As argued by Chaney (2006) and Andersson (2007), a substantial part of the fixed costs of establishing trading links is associated with the cost of acquiring knowledge about specific geographical product markets. Since knowledge is, to some extent, a public good that may spill over between economic agents, an individual firm’s export decisions are likely to be influenced by the export activities going on in other firms. Several empirical studies (Alvarez, 2007; Chevassus-Lozza et al. 2003; ISGEP (2008) reports an export market participation rate of 83 % in the Swedish manufacturing sector and the average export intensity (export value as share of the value of total sales) in those firms are 44 %. Corresponding figures for other countries included in the ISGEP study ranges between 30 – 81 % in export market participation rate and 18 – 60 % in firm-level export intensity.

\textsuperscript{33} ISGEP (2008) reports an export market participation rate of 83 % in the Swedish manufacturing sector and the average export intensity (export value as share of the value of total sales) in those firms are 44 %. Corresponding figures for other countries included in the ISGEP study ranges between 30 – 81 % in export market participation rate and 18 – 60 % in firm-level export intensity.
Barrios et al. 2003; Aitken et al. 1997; among others) have investigated the possibility of localized knowledge and information spillovers from domestic and multinational exporters. The results from these studies are, however, mixed and inconclusive, which motivates further analysis. The second purpose of this study is to examine if firms’ choices of export status is influenced by export decisions in neighboring firms.

The third objective of this paper is to analyze the impact of another source of knowledge on firms’ export behavior, namely the experiential knowledge that the firm accumulates when entering different geographical product markets. In fact, only a small fraction of non-exporting firms do enter into export markets in subsequent periods. Moreover, Swedish firm-level data reveal that firms that are already exporting are those that introduce most new export products and undertake most entries into new geographical export markets. These observations motivate a specific focus on the probability of a firm expanding its export activities to additional products and/or additional geographical destination markets. This study examines the importance of export market experiences in previous periods for the successful introduction of new export products and the successful establishment of a new geographical export link. This issue has not been targeted in previous empirical research of firms’ export behavior. Accordingly, this study contributes to the existing literature on firms’ export behavior by examining factors influencing the decision not only to participate in export markets but also the decision to expand export activities to comprise new products and/or new geographical markets.

The paper starts with a presentation of the synthesis of previous theoretical and empirical research on the determinants of firm-level export market participation and associated influences from agglomeration economies in Section 2. This section also presents the hypotheses to be tested in this paper and the econometric methodologies used to test these hypotheses are described in Section 3. Section 4 presents some descriptive statistics over the export behavior of Swedish firms followed by a presentation and discussion of the results from discrete choice model estimations in Section 5. Concluding remarks are summarized in Section 6.

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34 In a comparative study on the relationship between export and productivity, including firm-level evidences from 14 countries, ISGEP (2008) finds that firms that enter the export market after being a non-exporter during 3 years constitute a fraction that is generally less than 10 percent.
2. **Productivity and Firms’ Export Behavior – Stylized Facts and New Hypotheses**

Exporters are usually considered to be highly productive firms for, at least, three reasons. First, international markets are regarded as more competitive than domestic markets, implying that only the most efficient firms can survive in international markets. Second, when selling on foreign markets exporting firms generally incur higher transport and transaction costs. Third, participation in international markets makes firms more easily aware of innovations and technological development taking place abroad and by assimilating new knowledge gathered in international markets exporters may strengthen their position in both domestic and foreign markets. These influences of foreign market participations suggest that exporters are more productive than non-exporters. This section briefly reviews the literature on export and productivity.

2.1 **Self-selection and learning-by-exporting**

The theoretical literature on productivity differentials between exporting and non-exporting firms has mainly focused on two alternative (but not mutually exclusive) explanations. The first explanation points to self-selection of more productive firms into export markets. As the costs of selling goods abroad are higher than for domestic sales, export activities are profitable only for the most productive firms (Bernard et al. 2003; Melitz, 2003; Helpman et al. 2004; Yeaple, 2005). The additional costs associated with foreign sales consist of fixed export link investments as well as a per unit transaction cost, including transportation, tariffs etc. These costs provide an entry barrier that less productive firms have difficulties to overcome. Hence, ex-ante productivity differences between firms can partly explain why some firms start to export and others do not. Prevailing theoretical models of self-selection thus assume that firm-level productivity is exogenously given and no attention is given to the possibility of causality running from export to firm-level productivity\(^{35}\).

The second explanation to observed productivity differences between exporters and non-exporters points to the role of learning-by-exporting, i.e. the causality between export market participation and firm-level productivity. The focus in this approach is on differences in productivity

\(^{35}\) Still, the seminal model by Melitz (2003) predicts that an increase in the export market participation rate results in increased productivity at the aggregate industry level.
growth rates between exporters and non-exporters. The learning-by-exporting approach explains the higher productivity levels observed among exporters with the growth in productivity that is the result of export market participation. The higher productivity growth in exporting firms arises due to increased production scale, knowledge and technology transfers from foreign buyers and competitors and increased competition in international markets (Girma et al., 2004; Kostevc, 2009). These effects improve the productivity performance of firms ex-post their entry on export markets.

Empirical testing of the self-selection and learning-by-exporting hypotheses, using longitudinal micro-level data, has resulted in extraordinarily strong evidences of the self-selection hypothesis\(^{36}\). Exporters tend to have higher pre-entry productivity levels and also higher pre-entry productivity growth rates than firms that do not enter foreign markets. These results hold also after controlling for observed firm characteristics (size, industry, capital- and skill intensity) and lead to the conclusion that it is the most productive firms that sell abroad. Evidences supporting the learning-by-exporting hypothesis are somewhat more mixed: post-entry differences in productivity growth rates are significant in some studies, but when matched firms are compared differences are most often not significant. Hence, current evidences tell us that export market participation does not necessarily improve firm performance.

### 2.2 Explanations to Self-Selection

The conventional theoretical explanation to self-selection into export markets is that export market entry requires some fixed export link investments. This investment is associated with marketing and search for new customers, development of new distribution channels, adjustment of products to foreign product standards and market-specific customer preferences etc. In the presence of entry costs, only the most productive firms will make profits when selling abroad. This explains the observed ex-ante productivity differences between exporters and non-exporters. Moreover, if these link investments are sunk they provide an explanation to the observed high degree of persistence in firms’ export status (Roberts and Tybout, 1997; Bernard and Jensen, 2004; Esteve-Pérez, 2006). When entry costs are sunk, firms continue to export to a given market even if there is a negative exogenous shock in order to avoid paying the entry cost once more.

An interesting observation made by Alvarez (2007) is that only a limited number of exporting firms in Chile are permanent exporters, whereas the

majority of exporters enter and exit the export market from year to year. Nitsch (2009) presents similar findings in a study of import flows to Germany, showing that the duration of product-country-specific trade links are surprisingly low. These empirical observations are incongruous with the theoretical conjecture that fixed entry costs are sunk, thereby causing a persistent export behavior. The findings made by Alvarez (2007) and Nitsch (2009) rather indicate that the export behavior among the majority of exporting firms is stochastic. Hence, a critical issue concerning the self-selection process is whether the ex-ante higher productivity of export starters is due to an exogenous random shock, originating from a favorable exchange rate, decreased domestic input prices etc, or the result of a planned business strategy. López (2005) argues that "the self-selection process may well be a conscious decision by which firms purposefully increase their productivity with the clear intention of becoming exporters", (p. 624).

Empirical results presented by Hallward-Driemeier et al. (2002) have similar implications. Using plant-level data for five Asian countries, these authors find that those firms that started to export in the same year as the firm was established were significantly more productive than firms that became exporters after having served only the domestic market for some period before export market entry. Hallward-Driemeier et al. (2002) interpret these results as an indication of the initial market orientation of the firm (i.e. export- or domestic market orientation) influencing the firm's investment decision in an early stage of firm development. According to Hallward-Driemeier et al. (2002), the incentives to invest in productivity improvements originate from the higher returns available in international markets rather than the higher competitive pressure in those markets. However, López (2003, 2005) argues that the intense competition in international markets, both in terms of product prices and product attributes, requires of the successful exporter to be closer to the technological edge than non-exporting firms or firms exporting occasionally. As a consequence, permanent exporters have higher productivity and are able to make positive profits on their export sales in all periods. Occasional exporters, on the other hand, are firms that only sell on foreign markets when the conditions on those markets are relatively favorable compared to the conditions on the domestic markets.

Another explanation to different productivity trajectories between permanent exporters and occasional exporters may be the magnitude of the fixed export link investments required for becoming a permanent exporter compared to becoming an occasional exporter. It is likely that firms that successfully penetrate foreign markets have to make substantial link investments, which are sunk in nature, whereas the link investments made by sporadic exporters
are comparably small, allowing a stochastic rather than strategic export. Under such circumstances, the cost of exiting foreign markets is significant for an export-oriented firm addressing the export market in all periods, but negligible for a domestically oriented firm that only exports when the conditions in foreign markets are unusually favorable. This would result in a higher degree of persistence among firms that are export-oriented. In other words, the size of the sunk link investments is dependent on the firm’s export strategy, which in turn, reinforces export-oriented firms’ persistence in export markets.

Moreover, the export behavior of firms is likely to depend also on industry-specific factors, such as scale economies, market structures and the type of goods produced. In some industries the efficient scale of production is so large that the domestic market is too small for all firms in the industry, implying that the degree of export market participation among firms in such industries is very high. Limitations of domestic demand may also force firms in industries producing certain investment goods, for example some types of industrial machinery or transport equipment, to participate in foreign markets. Other industry characteristics that may affect firms export decisions are the R&D intensity and the incidence of patents in the industry. In industries where innovations and product development are crucial for firms’ survival, firms tend to make large investments in R&D. When these activities result in commercial products the firm achieves some temporary monopoly power, which may be prolonged by patents. In order to maximize monopoly profits firms strive to limit the quantity supplied on a given geographical market and instead increase production scale by penetrating many markets.

In sum, the self-selection process can be due to sunk entry costs or strategic business planning or a combination of both. The interesting observation is that there is an anticipated difference in productivity trajectories between permanent and occasional exporters, where the latter may have more in common with non-exporters. If the establishment of a permanent export link requires larger investments than temporary export market participation, permanent exporters are expected to have higher productivity than have occasional exporters and non-exporters.

2.3 Entry costs, knowledge and learning-effects

Several scholars have pointed out that a substantial fraction of the cost of establishing a new export link is associated with the gathering of knowledge and information about various characteristics of specific geographical
product markets and the search for new customers and distributors in these markets. Geographical markets are not homogenous and differ in consumer preferences, statutory product standards, price levels, import tariffs, transport and communication infrastructure etc. For each aggregate group of products or sectors there are some general market characteristics, which are sometimes global and sometimes specific for a given geographical market. Still, firms in most manufacturing sectors produce products that to some degree are differentiated from varieties produced by other firms in the industry. Consequently, the market that each firm faces with each of its product varieties has some characteristics that are of unique relevance for the individual product variety and firm and some characteristics that are relevant for an aggregate group of product varieties and an aggregate group of firms (sector). These features of product markets imply that knowledge that is internal as well as external to the individual firm may influence the size of the cost of entering new markets.

Focusing on firms’ internal knowledge related to foreign market conditions and business practices, this market or business knowledge can be regarded as a necessary factor for a successful exploitation of profit opportunities abroad. As argued by Johanson and Vahlne (1977; 1990) the relevant market knowledge is to a great extent of experiential nature and acquired from participation in international markets. When entering a new market, firms face uncertainty that is caused by the lack of experiential market knowledge. By the process of establishing export links and operating in foreign markets, firms accumulate knowledge and experiences that reduce this uncertainty and facilitate the introduction of new products and establishment of new export links. As a consequence, there may be a learning-by-exporting effect that reduces the cost of penetrating new export markets. This implies that the fixed cost of establishing an additional export link is a decreasing function of the firm’s internal knowledge about foreign markets. Evidences of significant positive effects of experiential knowledge found with regard to firms’ export intensity (Majocchi et al. 2005) and with regard to the performance of firms’ offshore subsidiaries (Carlsson et al. 2005). In the context of export market participation, such learning-by-exporting effects of firms’ previous export experiences are expected to influence both the probability that firms operate on established export links and firms’ decisions about export market expansion. Another important feature of knowledge and information as input factors is that in some respect they can be regarded as public goods that may spill over between economic agents (Romer, 1986). In the context of export market participation such spillover effects imply that firms’ export decisions may be influenced by the export behavior of neighboring firms. The origin of this external knowledge can be other trading firms (exporters and importers) or
multinational firms, which possess knowledge and information about foreign markets. External knowledge flows from these sources may reduce the export market entry costs for other firms.

Case studies of export behavior suggest that firms that penetrate foreign markets reduce entry costs for other firms, either through knowledge spillovers or by establishing commercial links or distribution infrastructure that can be shared with other firms (Aitken et al. 1997). Yet, empirical evidences are not conclusive. Aitken et al. (1997) and Alvarez (2007) find positive effects on the co-agglomeration of domestic and multinational firms on the probability of a domestic firm being an exporter, which implies that multinational enterprises may act like an export catalyst, who reduce the cost of foreign market entry for other firms. Alvarez (2007), Chevassus-Lozza et al. (2003) and Clerides et al. (1998) find that the regional concentration of export in an industry stimulates the export market participation rate among firms in that industry and region. However, Aitken et al. (1997), Barrios et al. 2003 and Bernard and Jensen (2004) find no indications of localized spillovers among domestic exporters. As existing empirical results are mixed and inconclusive a fourth hypothesis to be tested in this paper is that knowledge spillovers from other exporters stimulate export market participation and export market expansion.

2.4 Hypotheses about firms’ export behavior

Summarizing previous theoretical and empirical works on the relationships between firm-level productivity and export behavior one may conclude that firms’ export decisions can be random or strategic. This induces an anticipated difference in productivity performance across firms with different export behavior. Moreover, there may be learning-effects from export market participation that influences the cost of establishing or intensifying export links. Because of this, firms’ previous export experiences are likely to influence firms’ current export decisions. Firms may also learn from experiences made by other exporters, implying that the export decisions in one firm may be influenced by export experiences made by neighboring firms. These theoretical arguments are summarized in four testable hypotheses:

1. Permanent exporters have higher initial productivity levels than occasional exporters and non-exporters.
2. Experiences from occasional export market participation in one period increase the probability of a firm becoming a permanent exporter in the next period.

3. The probability of a firm expanding its export activities to new product varieties or new geographical markets increases with previous export experience.

4. Firms’ export decisions are influenced by the export activities in neighboring firms.

The next sections in this paper test these hypotheses on Swedish micro-level data on manufacturing firms.

3. **Methodology**

Dynamic models of export market participation assume that a firm facing the discrete choice of exporting or not exporting will choose to export if the expected present value of exporting exceeds the expected present value of not exporting (Roberts and Tybout, 1997). In order to test the hypothesis that productivity differences can explain firms’ export status, the subsequent analysis follows a variant of this approach, used by Alvarez (2007). This approach assumes that firms choose to participate in the export market throughout the time-sequence that maximizes the present value of expected profits.

3.1 **Econometric models**

Focusing on three different time-sequences in export market participation, firms’ choice set consists of three choices: exporting in each year over the whole period, exporting only in those years where exogenous factors make expected profits from exporting higher than the expected profits from selling the output on the domestic market, or not exporting in any year during the whole period. As the econometrician typically cannot observe ex-ante profit expectations, firms’ ex-post export behavior is the only observable variable. Denoting the observed export status over the period 1997 – 2004 by $k \in K=\{1,2,3\}$, then, ex-post we may assume that a profit maximizing firm has chosen a sequence of participation $j \in K$ whose expected profits exceed the expected profits of any other alternative $k$: 
\[ \Pi^j(v_0, z_r) > \Pi^k(v_0, z_r), \quad j \neq k, \quad j, k \in \{1, 2, 3\} \]  

where the expected profit (\( \Pi \)) is a function of initial firm characteristics, \( v_0 \), and some location-specific factors exogenous to the firm, \( z \). Assuming a reduced form of the expected profit function associated with each alternative:

\[ \Pi^k(v_0, z_r) = \beta_k 'X + \epsilon_k \]  

where \( X \) is a vector containing firm- and location specific explanatory variables and \( \epsilon \) is an error term, assumed to be identically and independently distributed and following an extreme value distribution. With this assumption the model is a well-known multinomial logit, giving the probability of firm \( i \), located in region \( r \) choosing alternative \( k \) by:

\[ \Pr(k_i = k | v_{0i}, z_r) = \frac{\exp(\beta_k 'X)}{\sum_{k=1}^{3}\exp(\beta_k 'X)} \]  

By estimating this multinomial logit model we may test hypothesis 1, i.e. whether initial firm characteristics can explain firms’ export behavior.

In order to examine the influences of firms’ previous export experiences on current export decisions, the data set is divided into two periods so that the impact of the observed export status in the first period on export decisions in the second period can be analyzed. This issue is investigated through two complementary approaches. First, we examine if firms that have some export experiences in period 1 are more likely to become successful (permanent) exporters in period 2 (hypothesis 2). Second, we investigate the impact on previous export experiences, on the probability that a firm expands on foreign markets, either by introducing new export products or by penetrating new geographical markets (hypothesis 3).

The second hypothesis is tested by estimating the impact of the observed export status in the first period on the probability of a firm changing from not being a permanent exporter in period 1 to becoming a permanent exporter in period 2. Consequently, only firms that are non-exporters or occasional exporters in period 1 are included in this estimation. In accordance with the discussion in section 2, we expect sunk market entry costs to be negligible when exporting occasionally, implying that the expected profits for a firm that do not export permanently are independent of any occasional export activities in coming periods. However, the cost of
establishing a permanent export link is expected to be significant, but possibly smaller, for firms that have some previous experience from selling to foreign markets. Hence, the probability of becoming a permanent exporter hinges upon the expected profits from investing in a permanent export link compared to the expected profits from not doing so. This implies that the relevant choice context is the binary discrete choice of becoming a permanent exporter or not in the second period. This binary choice setting takes the form:

\[
\begin{cases}
\Delta \Pi > \Delta \Pi = 0 & \text{if} \quad \Pi^{\text{new}}_{i,j}(v_{0,j-1}, \Delta v_{i,j-1}, z_{r,j-1}, k_{i,j-1}) > \Pi^{\text{old}}_{i,j}(v_{0,j-1}, \Delta v_{i,j-1}, z_{r,j-1}, k_{i,j-1}) \\
0 & \text{otherwise}
\end{cases}
\]

where the expected profit functions, as in equation 1, is assumed to depend on initial firm and location characteristics \((v_0, z_r)\) but also on the change in firm characteristics over period 1 \((\Delta v_{i,j-1})\) and on the firm’s export status in period 1, \(k_{i,j-1}\). The export status in the first period is controlled for by a dummy variable taking the value 1 if the firm is an occasional exporter in period 1 and zero otherwise. The variables reflecting the change in firm characteristics is included to control for improvements in firm performance that would stimulate export market participation, independently of any export experience in period 1. The probability of becoming a permanent exporter is, accordingly, given by:

\[
\Pr(y_{i,j} = 1) = \Pr\left(\lambda_1 v_{0,j-1} + \lambda_2 \Delta v_{i,j-1} + \lambda_3 z_{r,j-1} + \mu_i > \Pi_{i,j}^{\text{old}}\right)
\]

The assumption that the error term follows a normal distribution with zero mean and constant variance permits estimation of Equation 5 as a binary probit model.

Addressing the third hypothesis, which concerns the probability of a firm expanding its sales on foreign markets by establishing export links to new geographical markets or introducing new export products, it is again predicted that these decisions are influenced by firm- and location-specific variables. Of particular interest are the firm’s experiences from export market participation in previous periods. Experiences from export activities are supposed to generate learning effects, which reduce entry costs and thereby increase the probability of entry on new export markets.

However, as we are only interested in successful entries in the sense that they result in a permanent export link, the choice of entering a new foreign product market also includes the choice of permanent export market
participation. From an econometric point of view, there is an identification problem since these two choices are not independent, i.e. the decision to expand on foreign markets in period 2 is conditional upon the choice of being a permanent exporter in period 2. This problem arises due to the selection bias that follows from the definition of a successful entry: by definition, only permanent exporters in period 2 can self-select to the group of firms that expand their export activities in that period. This self-selection bias is particularly important in this context because we expect that firms’ export market experiences in previous periods increase not only the probability of expanding export activities but also the probability of permanent export market participation in the current period. From estimates of a standard probit model it is difficult to determine if the effect of export experiences on the probability of export expansion extends beyond its contribution to the probability of permanent export market participation.

One way to avoid this identification problem would be to include only those firms that are permanent exporters in period 2. However, we hypothesize that there is a systematic difference between permanent exporters and other firms and disregarding these other firms would generate another type of selection bias. To illustrate this problem, let us, for simplicity, assume that export experience is the only observable variable that influences firms’ export decisions. This assumption implies that the sample of firms that self-select to the group of firms that expand their export activities will be a sample dominated by experienced firms since firms with experiences from export markets are more likely to be permanent exporters. However, this non-random aspect of the selected sample does not cause the selection bias but the bias occurs because some inexperienced firms will also be among the permanent exporters. Due to some unobserved factor, say entrepreneurial skills, some inexperienced firms will choose to export permanently. Assuming that entrepreneurial skills have a positive effect on the probability of expanding on export markets, the effect of experience on export expansion will be underestimated, since inexperienced firms in the selected sample are unusually entrepreneurial.

One way to resolve the identification problem and avoid the problem of selection bias described above is to use a two-step estimation procedure introduced by Heckman (1979). This procedure includes one selection equation and one outcome equation which are not conditioned to be independent. The outcome equation gives the probability of expanding on foreign markets as a function of the expected profit from this new export activity:
Market experiences and export decisions in heterogeneous firms

\[ e_{ij} = \begin{cases} 1 & \text{if } \Pi_{ij}^{n-1}(v_{0j,i-1}, \Delta v_{ij,i-1}, z_{r,ij}, k_{ij,i-1}) > 0 \\ 0 & \text{otherwise} \end{cases} \]  \hspace{1cm} (6)

Hence, the dependent variable takes the value 1 if the firm enters on new geographical product markets or zero otherwise. Hence, the outcome equation takes the form of a binary probit regression model:

\[ \Pr(e_{ij} = 1) = \Pr\left( \gamma_1 M_{P,i-1} + \gamma_2 M_{D,i-1} + \gamma_3 v_{0j,i} + \gamma_4 z_{0r,ij} + \eta_0 > 0 \right) \]  \hspace{1cm} (7)

(Outcome equation)

Among the explanatory variables in this model there are two dummy variables: \( M_{P,i-1} \), which reflects if the firm has experience from exporting multiple products in period \( i-1 \) and \( M_{D,i-1} \), which reflects if the firm’s export activities have involved multiple export destinations in period 1. In practice these dummy variables take the value 1 if the firm’s export activities in period 1 have comprised at least 6 products and at least 6 destinations, respectively. In addition, the outcome equation also includes a vector of other firm characteristics and a vector of location-specific variables, both measured at the beginning of period 2.

As explained above the dependent variable may take the value 1 only if the firm decides to be a permanent exporter in period 2. Assuming that this selection process depends on a profit condition, we can write:

\[ p_{ij} = \begin{cases} 1 & \text{if } \Pi_{ij}^{n-1}(v_{0j,i}, z_{0r,ij}, k_{ij,i-1}) > \Pi_{ij}^{n-0}(v_{0j,i}, z_{0r,ij}, k_{ij,i-1}) \\ 0 & \text{otherwise} \end{cases} \]  \hspace{1cm} (8)

Assuming normally distributed disturbances, a probit model estimates the probability that a firm chooses to be a permanent exporter in period \( i \) by:

\[ \Pr(p_{ij} = 1) = \Pr\left( \alpha_1 v_{0j,i} + \alpha_2 z_{0r,ij} + \alpha_3 k_{ij,i-1} + \eta_{ij} > \Pi_{ij}^{n-0} \right) \]  \hspace{1cm} (9)

(Selection equation)

If the error terms in Equation 7 and 9 are correlated a standard probit regression of equation 6 will provide biased results, which implies that the two-step probit model with selection is preferable.
3.2 Explanatory Variables

Following previous empirical work in this research field, three types of variables are included in the regression analyses: firm performance variables, variables reflecting firms’ export market experiences in previous periods and variables reflecting the characteristics of the region where the firm is located. In this subsection, the measurement of the firm- and location-specific variables is briefly presented.

**Firm characteristics**

Given results from previous empirical research the firm-level variable of particular interest is the productivity level, since this is an indicator of the firm’s competitiveness. As data on firm-level capital stocks are not available, this study focuses on labor productivity measured as the value added per employee. Another variable that may influence firms’ export decisions is the firm’s human capital intensity. This variable can be presumed to reflect the magnitude of sales and marketing efforts in the firm as well as investments in product and process development. As a consequence one would expect firms with high human capital intensity to be more competitive in international markets and therefore more likely to participate in export markets. The human capital intensity is measured as the share of employees that have at least three years of university education. Moreover, the size of the firm is an important variable since it reflects the efficient scale of production. If the minimum efficient scale of production is very large for some product groups, firms producing these kinds of products are more likely to export simply because they have to overcome the limitation of the domestic market demand. Furthermore, the corporate ownership of the firm is included among the regressors in the form of a dummy variable for firms belonging to a Swedish-owned MNE and a dummy variable for firms belonging to a foreign-owned MNE. These variables are expected to increase the probability of export market participation, since a large fraction of total world trade flows takes place on trading links between firms within the same MNE.

All firm-level variables presented above are expected to have a positive influence on the probability of a firm being an exporter. Indeed, all these firm-specific variables are also likely to be correlated. Theoretically, however, they affect firms’ competitiveness through different economic mechanisms for what reason it is of interest to include them all together.
Location-specific Characteristics

Previous research on firms’ export behavior observes agglomeration effects, which may stimulate firms’ export market participation. Some authors argue that these agglomeration effects arise primarily due to incidence of external flows of knowledge and information about foreign market conditions. With the purpose of examining such spill over effects we follow Aitken et al. (1997), Barrios et al. (2003), Alvarez (2007) (among others) and include three variables reflecting the regional concentration of industry activities. These concentration measures are defined on the finest regional level; municipalities. For the given time period, there are 288 municipalities in Sweden and the municipality concentration of 1) export activities, 2) MNE enterprises and 3) overall industry activity are presumed to have positive influences on the probability of a firm being a permanent exporter.

First, we consider the possibility of external economies in exporting activities arising from the geographical agglomeration of exporters. Similar to previous studies, this variable is calculated at the industry-municipal level. However, recognizing the fact that markets are defined by groups of products rather than by industry classifications, we make use of the information about firms’ export by product group available in our data. The statistical classification of product groups (HS or SITC) is strongly related to the statistical classification of industries (NACE). Still, firms that have not produced the exported goods themselves account for a substantial part of aggregate international export flows. If one only includes manufacturing firms when calculating the measures of export concentration within an industry, the available knowledge and information about foreign markets are likely to be underestimated since the market information possessed by retail trading firms are not included. Furthermore, many manufacturing firms export products that are classified to another industry than the industry in which they have the majority of their employment. Therefore, the measure of local concentration of an industry’s exporting activities used here is based on the total number of firms (manufacturers and retail traders) in a municipality that are exporting products classified to a two-digit industry code. Following Glaeser et al. (1992) and Henderson (1995) (among others) the measure of local agglomeration of export activities is calculated as the municipality’s share of the total number of firms that export goods produced by a specific industry normalized by the municipality’s share of the total number of firms in that industry. As argued by Aitken et al. (1997) this measure puts its emphasize on the role of localized export spillovers as it

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37 This classification follows the key between CN codes and NACE codes provided by Statistics Sweden.
implies that there is a spatial export concentration only if this concentration exceeds the geographical concentration of the industry as a whole.

Second, a variable reflecting the geographic concentration of the overall economic activity is calculated. There are many factors that may induce agglomeration of firms and this variable is included to control for agglomeration economies that are not related to export activities. Using the same methodology as for export concentration, this variable is calculated as the municipality-industry share of national industry employment divided by the municipality’s share of total manufacturing employment.

Third, the role of MNE’s as disseminators of knowledge and information about foreign markets are approximated by the municipality’s share of the total number of firms belonging to a MNE in a given industry relative to the municipality’s share of the total number of firms in that industry.

4. The export behavior of Swedish Firms

The empirical testing of the hypothesis presented in the previous chapter is based on a micro data set of Swedish firms during the period 1997 – 2004. Observations are at the firm level and the location of each firm is defined at the municipality (local government area) where the major share of the firm’s employees is located. The same method is applied for the industry classification of each firm; firms are classified to the industry in which they have the major share of their employment. Besides firm characteristics, the data set includes the export activities of each firm, classified at the level of 8-digit product groups and with regard to destination country.

In order to distinguish between firms with different export behavior, the export status of each firm is initially identified over the whole period 1997 – 2004. A permanent exporter is defined as a firm that exports in each year throughout this period. An occasional exporter is a firm that exports only in some of the eight years, and a non-exporter is a firm that does not export in any year. This identification of export status implies that only firms that exist over the whole period is included in the analysis. Moreover, firms with fewer than 10 employees on average over the period are excluded from the analysis. With this censoring, the data set used includes 3828 firms.

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38 This data censoring may induce a selection bias as all firms in the selected sample performs sufficiently well in terms of sales and productivity to survive throughout the whole period. As a consequence the influence of the explanatory variables on export behavior may be underestimated.
Market experiences and export decisions in heterogeneous firms

Descriptive statistics in Table 5.1 show that almost 65 % of the firms are permanent exporters, whereas 25 % are occasional exporters and only 10 % are non-exporters. 39 % of the firms exporting permanently belong to a multinational enterprise. The corresponding figure for occasional exporters is 10 % and only 6 % for non-exporters. Moreover, 29 % of those firms that are permanent exporters are incorporated in a Swedish owned MNE whereas only 10% are foreign owned. Table 5.1 supports previous findings that exporters are, on average, superior to non-exporters in terms of firm size, human capital intensity and labor productivity. Furthermore, the figures in Table 5.1 suggest that firms exporting permanently are larger, more intensive in human capital and have higher labor productivity than firms that export occasionally.

Table 5.1 Characteristics of firms with different export status 1997-2004

<table>
<thead>
<tr>
<th></th>
<th>Permanent Exporters</th>
<th>Occasional Exporters</th>
<th>Non-exporters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of firms (1997-2004)</td>
<td>2476</td>
<td>972</td>
<td>380</td>
</tr>
<tr>
<td>Percentage of firms belonging to a Swedish MNE (1997)</td>
<td>29</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Percentage of firms belonging to a foreign MNE (1997)</td>
<td>10</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mean</td>
<td>134.72</td>
<td>39.00</td>
<td>37.90</td>
</tr>
<tr>
<td>Median</td>
<td>39.00</td>
<td>18.00</td>
<td>16.00</td>
</tr>
<tr>
<td>Percent of employees with university education (1997)</td>
<td>4.11</td>
<td>2.17</td>
<td>2.07</td>
</tr>
<tr>
<td>Labor productivity (value added per employee in thousands SEK, 1997)</td>
<td>475.53</td>
<td>427.8</td>
<td>397.15</td>
</tr>
</tbody>
</table>

To investigate the influence of firms’ previous export experiences on the decision about current export participation, the data is divided into two sub-periods: 1997 – 2000 and 2001 – 2004. Firms are classified according to the consistency in export behavior over each sub-period. A contingency analysis of firms’ export behavior over the two periods is displayed in Table 5.2. This table shows that there is a high persistence in export behavior over the two periods; firms being permanent exporters in period 1 most likely remain
permanent exporters in period 2, whereas a non-exporter in period 1 most likely abstains from foreign market participation also in period 2.

Still, some firms do change export status between the two periods and the figures in the contingency table suggest that it is more likely to become a permanent exporter in period 2 if the firm is exporting sporadically in period 1 than if the firm is a non-exporter in period 1. Thus, the figures in Table 5.2 give some support to the hypothesis that there are learning-effects from occasional export activities, which amplify the probability that the firm becomes a permanent exporter.

Table 5.2 Firm export status across two periods

<table>
<thead>
<tr>
<th>Export Status 2001 – 2004</th>
<th>Permanent exporter</th>
<th>Occasional exporter</th>
<th>Non-exporter</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent exporter</td>
<td>2476</td>
<td>119</td>
<td>7</td>
<td>2602</td>
</tr>
<tr>
<td>Occasional Exporter</td>
<td>222</td>
<td>314</td>
<td>128</td>
<td>664</td>
</tr>
<tr>
<td>Non-exporter</td>
<td>25</td>
<td>157</td>
<td>380</td>
<td>562</td>
</tr>
<tr>
<td>Total</td>
<td>2723</td>
<td>590</td>
<td>515</td>
<td>3828</td>
</tr>
</tbody>
</table>

\[ \chi^2 \text{- value (significance)} = 2966.78 (0.000) \]

Turning the interest to firms’ entries on new export markets, this paper only considers successful entries in the sense that the entry results in a permanent presence of the firm on a specific geographical product market. Since markets can be defined both in geographical terms and in terms of products, export market entry can be defined in two ways: 1) entry on a new geographical market and 2) introduction of a new product. We identify these two types of entries by distinguishing these markets and products where the firm has positive export in all years in the period 2001 - 2004 and where export was zero in all years in the period 1997 - 2000. A contingency analysis of firms export market status in period 1 and export expansion in period 2 is shown in Table 5.3.

The figures in table 5.3 reveal that the majority (57 %) of those firms that were permanent exporters in the first period introduced new export products in the second period. 19 % of those firms also entered on new geographical markets in the second periods. These percentage shares are high compared to
the fractions of firms that entered on new exports markets among occasional exporters or non-exporters. Only 28% of the firms that were exporting occasionally in period 1 entered on new destinations or introduced new products in period 2. The corresponding figure for non-exporters in period 1 is as low as 4%.

Table 5.3 Previous Export Status and Export market expansion

<table>
<thead>
<tr>
<th>Export Status 1997 – 2000</th>
<th>Entry on new export destinations</th>
<th>Introduction of new export products</th>
<th>No entry</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent exporter</td>
<td>498 (19%)</td>
<td>1497 (58%)</td>
<td>607 (23%)</td>
<td>2602</td>
</tr>
<tr>
<td>OccasionalExporter</td>
<td>65 (10%)</td>
<td>120 (18%)</td>
<td>479 (72%)</td>
<td>664</td>
</tr>
<tr>
<td>Non-exporter</td>
<td>11 (2%)</td>
<td>9 (2%)</td>
<td>542 (96%)</td>
<td>562</td>
</tr>
<tr>
<td>Total</td>
<td>574 (2%)</td>
<td>1626 (2%)</td>
<td>1628 (2%)</td>
<td>3828</td>
</tr>
</tbody>
</table>

χ²-value (significance) 1305.06 (0.000)

The figures in Table 5.3 signify that firms’ export experiences may have an influence on the probability of export market expansion. A stronger indication of knowledge accumulation from participation in foreign markets would be if there were a relationship between the scope of export experiences in one period and the probability of export market expansion in the next period. The scope of a firm’s export experiences in a given period can be measured as the number of product-specific geographical market that the firm exports to. Using this measurement of export experience, the contingency analysis in Table 5.4 shows that the larger the scope of export activities in period 1, the more likely it is that the firm establishes a new export link or introduces a new product on the export market in period 2. In

\[ \delta_{ij} = 1 \text{ if the firm export product variety } i \text{ to destination } j \text{ and takes a zero value otherwise.} \]
fact, only 64 of the 1144 firms with the largest export experience in period 1 abstain from expanding on export markets in period 2.

Table 5.4 Export experiences and export market expansion

<table>
<thead>
<tr>
<th>Scope of Export Experience&lt;sup&gt;a&lt;/sup&gt; 1997 – 2000</th>
<th>Export market entry 2001 – 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Entry on new export destinations</td>
</tr>
<tr>
<td>High</td>
<td>185</td>
</tr>
<tr>
<td>Medium</td>
<td>253</td>
</tr>
<tr>
<td>Low</td>
<td>125</td>
</tr>
<tr>
<td>Zero</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>574</td>
</tr>
</tbody>
</table>

<sup>a</sup> The scope of export experience is measured as the number of product specific export destinations a firm exports to. See footnote 6 in the text.

The information presented in Tables 5.1 – 5.4 gives some support to the hypotheses about firms export behavior formulated in Section 2. The next section presents the results of the estimations of the econometric models formulated in the previous Section, which are used to test these hypotheses more carefully.

5. **Empirical Results**

This section presents the results of the empirical analysis of the influence from firm characteristics, export experiences and location-specific factors on firms’ export decisions.

5.1 **Differences between firms with different export status**

The multinomial logit regression model presented in Equation 3 explains differences in firms’ export status with differences in initial firm-level characteristics and location-specific factors. Consequently, all variables in the model are measured at the beginning of the period. In the estimations the status nonEXPORTER has been used as the reference outcome, implying that
the estimated regression coefficients reflect the impact of each explanatory variable on the probability of being a permanent respectively an occasional exporter relative to being a non-exporter.

The estimated coefficients in the multinomial regression are presented in Table 5.5. These estimates reveal that the size of the firm and its labor productivity significantly increase the probability of export market participation both on a permanent and an occasional basis. Human capital intensity and affiliation to a domestic MNE are variables that appear to increase the probability of a firm being a permanent exporter compared to a non-exporter but do not seem to have any significant influence on the probability of exporting occasionally. Moreover, firms affiliated to a foreign MNE seem less likely to be occasional exporters, whereas a foreign MNE ownership does not have any significant impact on the probability of having a permanent export status. This outcome shows that firms affiliated to a foreign MNE, in general have a persistent export behavior, be it as an exporter or non-exporter.

Among the location-specific variables, the local concentration of exporters has a significant positive influence on the probability of a firm being a permanent or occasional exporter. Also the local concentration of overall industry employment shows a significant positive impact on the probability of permanent export market participation, but for sporadic export this variable is not significant. The local concentration of MNE is, on the other hand, not significant for any outcome, which is surprising given some previous empirical findings. One possible explanation, put forward by Sjöholm (2000), is that when firm-level ownership is already controlled for, spillover effects from MNEs are likely to be of importance only for independent domestic firms. Another possible explanation is that there are some multi-collinearity between the variables reflecting concentration of exporters respectively concentration of MNEs. However, when dropping the variable measuring local concentration of exporters, the estimated coefficient for MNE concentration is still negative.

Moreover, as stressed by Aitken et al. (1997), there is a possibility that the variables reflecting local concentration of exporting firms, respectively, firms affiliated to a multinational company group are determined simultaneously with the export decision of individual firms. This will be the case if, for instance, output-supply shocks are common to firms in a given

---

40 To examine this possibility, the MNE concentration variable has been interacted with a dummy variable that takes the value 1 for independent domestic firms. However, the estimated coefficients for this variable are not significant for any outcome.
industry and location, or if MNEs are attracted to municipalities and industries that offer favorable conditions for exporting. This endogeneity problem implies that the estimated coefficients of these variables must be interpreted with some caution.

Table 5.5 Results of multinomial logit regression including three export statuses

<table>
<thead>
<tr>
<th>Regression Coefficients (Standard error)</th>
<th>Difference in Coefficients (Standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Permanent Export</td>
</tr>
<tr>
<td>Size (number of employees)_{1997}</td>
<td>0.2337** (0.0034)</td>
</tr>
<tr>
<td>Human capital intensity_{1997}</td>
<td>3.1915* (1.4570)</td>
</tr>
<tr>
<td>Labor productivity_{1997}</td>
<td>0.0035** (0.0005)</td>
</tr>
<tr>
<td>Domestic MNE_{1997} (dummy)</td>
<td>1.1814** (0.2848)</td>
</tr>
<tr>
<td>Foreign MNE_{1997} (dummy)</td>
<td>0.2587 (0.4240)</td>
</tr>
<tr>
<td>Local concentration of industry exporters_{1997}</td>
<td>0.4252** (0.1288)</td>
</tr>
<tr>
<td>Local concentration of MNEs in the industry_{1997}</td>
<td>-0.0173 (0.0642)</td>
</tr>
<tr>
<td>Local concentration of industry employment_{1997}</td>
<td>1.1844* (0.5366)</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.2712 (0.4636)</td>
</tr>
</tbody>
</table>

Pseudo R²

No. of observations 3828

** Significant at 1 % level, * Significant at the 5 % level. All regressions include 2-digit industry dummies. The base-level outcome is non-exporter.
The regression results in the first two columns of Table 5.5 indicate that there is a difference between permanent and non-exporters and a difference between occasional and non-exporters. However, these figures do not explicitly reflect the differences between permanent and occasional exporters. Re-estimating the multinomial logit model with the occasional export status as reference outcome gives the difference in coefficients between permanent and occasional exporters along with the associated standard errors. These differences in coefficients between permanent and occasional exporters (presented in the last column of Table 5.5) are statistically significant for all variables that have a significant impact on any outcome in the multinomial logit model.

The conclusion to be drawn from Table 5.5 is that there are significant differences in firm characteristics between permanent and occasional exporters, where the former appear to be larger, more intensive in human capital and more productive than the latter. Moreover, it seems that agglomeration effects from geographic concentration of exporters and industry employment have a stronger impact on the probability of permanent export market participation than on the probability of having occasional sales to foreign markets.

In order to facilitate the economic interpretation of the coefficients of the multinomial logit model, the marginal effect of a unit change in the explanatory variables on the probability of a given outcome are presented in Table 5.6. The marginal effects are calculated at the mean values of the independent variables, which are presented in the last column of Table 5.6. As shown by these figures, the marginal effects of a unit change in the explanatory variables on the probability of each outcome (permanent or occasional export) are almost mirror images of each other. This finding suggests that the relevant choice of export strategy for most firms in the sample is that of permanent versus occasional export market participation.

Moreover, the Hausman test of the IIA (Independence of Irrelevant Alternatives) property is applied to examine if the disturbances in Equation 2 are independently distributed across choice alternatives. The test shows that the error terms are not independent, which indicates that the IIA property is violated as two choice alternatives share common unobserved attributes. In this case, the violation of the IIA property signifies that occasional exporters have more attributes in common with non-exporting firms than with firms exporting permanently. The violation of the IIA property implies that the multinomial logit regression applied above is inefficient for forecasting purposes. However, for hypothesis testing, the IIA property is not of particular relevance (Dow et al. 2004). Consequently, the results of the
multinomial logit model can be interpreted in support of the hypothesis that there are significant differences between firms exporting permanently and firms exporting occasionally.

Table 5.6 Estimated marginal effects

<table>
<thead>
<tr>
<th>Variable mean</th>
<th>Permanent Export</th>
<th>Occasional Export</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (employees)</td>
<td>0.00065 (0.00012)</td>
<td>-0.00059 (0.00012)</td>
<td>99.221</td>
</tr>
<tr>
<td>Human capital intensity (%)</td>
<td>0.00708 (0.16457)</td>
<td>-0.00703 (0.16418)</td>
<td>3.3</td>
</tr>
<tr>
<td>Labor productivity</td>
<td>0.00032 (0.00005)</td>
<td>-0.00032 (0.00005)</td>
<td>445.370</td>
</tr>
<tr>
<td>Domestic MNE (dummy)</td>
<td>0.14392 (0.01641)</td>
<td>-0.14201 (0.01637)</td>
<td>-</td>
</tr>
<tr>
<td>Foreign MNE (dummy)</td>
<td>0.15717 (0.02124)</td>
<td>-0.15699 (0.02116)</td>
<td>-</td>
</tr>
<tr>
<td>Local concentration of industry exporters</td>
<td>0.02299 (0.00981)</td>
<td>-0.02200 (0.00978)</td>
<td>1.527</td>
</tr>
<tr>
<td>Local concentration of MNEs</td>
<td>-0.00642 (0.00354)</td>
<td>0.00640 (0.00353)</td>
<td>1.334</td>
</tr>
<tr>
<td>Local concentration of industry employ.</td>
<td>0.05896 (0.02621)</td>
<td>-0.05622 (0.02612)</td>
<td>0.329</td>
</tr>
</tbody>
</table>

(1) The marginal effect (dx/dy) of a change in a dummy variable is calculated for a discrete change from 0 to 1.

5.2 The probability of becoming a permanent exporter

Addressing the hypothesis of learning effects from export market participation that reduce entry costs, we start by testing the hypothesis that firms that export occasionally in period 1 are more likely to become permanent exporters in period 2 than firms with no export experience in the
first period. To test this hypothesis, we only include those firms that were occasional or non-exporters in period 1 in the analysis (1226 firms) and apply the probit model specified in Equations 4 and 5. This model includes firm characteristic variables measured at the beginning of period 1 as well as variables measuring the change in those characteristics over period 1. Moreover, the location-specific variables, calculated as the mean values over period 1, are included. Finally, the model also includes a dummy variable for export status in period 1 (1 = occasional export).

Table 5.7 presents the results of the probit regression. Among all regressors, only two variables show a significant impact on the probability of becoming a permanent exporter: the dummy for occasional export in period 1 and the dummy variable for firms affiliated to a Swedish MNE. The marginal effect (calculated for a discrete change from 0 to 1) of previous export experience implies that if the firm acquires some experience from foreign market participation in the first period the probability of becoming a permanent exporter in the following period increases by 0.28. The marginal effect of the ownership dummy implies that if a firm belongs to a Swedish MNE by the end of period 1 this increases the probability of being a permanent exporter by 0.22.

The results of the probit regression presented in Table 5.7 indicate that there are significant positive effects of previous export experiences on the probability of becoming a permanent exporter. This outcome can be interpreted as an indication of the presence of learning-effects from occasional export market participation, which increases the probability of a firm becoming a successful exporter that stays competitive in foreign markets on a permanent basis.
### Table 5.7 Results of Probit regression: Probability of becoming a permanent exporter

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression coefficient</th>
<th>Std. error</th>
<th>Marginal effects (1)</th>
<th>Variable mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size, 1997</td>
<td>0.0012</td>
<td>0.0013</td>
<td>0.0003</td>
<td>28.401</td>
</tr>
<tr>
<td>Human capital intensity, 1997</td>
<td>-1.6470</td>
<td>1.0964</td>
<td>-0.3874</td>
<td>0.020</td>
</tr>
<tr>
<td>Labor productivity, 1997</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.00001</td>
<td>387.40</td>
</tr>
<tr>
<td>Growth in human capital intensity, 1997-2000</td>
<td>-1.9578</td>
<td>1.5962</td>
<td>-0.4605</td>
<td>0.007</td>
</tr>
<tr>
<td>Growth in labor productivity, 1997-2000</td>
<td>-0.0114</td>
<td>0.1110</td>
<td>-0.0027</td>
<td>1.167</td>
</tr>
<tr>
<td>Domestic MNE, 2001 (dummy)</td>
<td>0.7283***</td>
<td>0.1509</td>
<td>0.2201</td>
<td>-</td>
</tr>
<tr>
<td>Foreign MNE, 2001 (dummy)</td>
<td>0.4610</td>
<td>0.3033</td>
<td>0.1322</td>
<td>-</td>
</tr>
<tr>
<td>Occasional export in period 1 (dummy)</td>
<td>1.2467***</td>
<td>0.1122</td>
<td>0.2791</td>
<td>-</td>
</tr>
<tr>
<td>Local concentration of industry export, 1997-2000</td>
<td>0.0459</td>
<td>0.0765</td>
<td>0.0108</td>
<td>1.305</td>
</tr>
<tr>
<td>Local concentration of industry MNEs, 1997-2000</td>
<td>-0.0491</td>
<td>0.0395</td>
<td>-0.0116</td>
<td>0.690</td>
</tr>
<tr>
<td>Local concentration of industry employment, 1997-2000</td>
<td>0.2099</td>
<td>0.2321</td>
<td>0.0494</td>
<td>0.231</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.8404***</td>
<td>0.3225</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mc Fadden Pseudo R²</td>
<td>0.20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>1226</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The marginal effects (dx/dy) are calculated at the mean of the independent variables. For dummy variables, the marginal effects are calculated for a discrete change from 0 to 1. ** Significant at the 1 % level.
5.3 Probability of expanding sales to new export markets

The final issue to be addressed in this paper is the probability of a firm expanding its export activities to include additional products and/or additional destination markets. The Heckman selection probit model presented in Equations 6–9 is estimated separately for two firm choices: 1) introduction of a new export product and 2) establishment of a new geographical export link. We only consider new successful entries in the sense that they result in a permanent export status for the firm of that product or on that destination link throughout period 2. Moreover, we only consider a ‘pure’ entry in the sense that an entry is identified only if a firm starts to export products in a 8-digit product group in which it had no export in any year in period 1 or if the firm starts to export to a country which it did not export to in any year in period 2. The results of these estimations are presented in Table 5.8.

The estimation results of the outcome equation, presented in the top of Table 5.8, indicate that the human capital intensity and affiliation with multinational corporations, domestic and foreign, significantly increase the probability of a firm introducing an additional product on the export market. Moreover, the dummy variable for multi-product export experience in period 1 shows a strongly significant positive impact on the probability of introducing new products. Experience from exporting to multiple geographical markets, on the other hand, does not seem to have any significant influence on the probability of expanding the range of products sold abroad.

Looking at the probability of establishing new export links, the regression results suggest that firms with multi-market export experience in period 1 are more likely to enter new markets than firms that only exported to few markets in period 1. Experience from exporting many products in period 1 has, on the other hand, a negative, though not significant impact on the probability of establishing new geographical export links. The regression results suggest that such firms rather expand their export activities by introducing additional products. However, a large fraction (42 %) of multi-product firms also export to multiple destinations, implying that there is multi-collinearity between the two variables reflecting export experiences. It is therefore somewhat difficult to separate the impacts of these two variables. As it appears, however, firms that already export multiple products are more likely to introduce new products on foreign markets. This is an expected outcome since large multi-product firms are likely to be more innovative and
develop new products more frequently than firm’s manufacturing few products. Moreover, large multi-product firms already export to many destination countries, which implies that they are more likely to expand their export activities by adding more product varieties.

As in the case of introduction of new export products, affiliation with MNEs (domestic and foreign) seems to increase the probability of geographical expansion. A comparison of the impacts of other firm-level variables on the two types of export market expansion points to the conclusion that human capital is of larger importance for the probability of expanding export sales by introducing new products, whereas geographical export expansion seems to be more dependent on firm-level labor productivity. This finding indicates that the competitiveness of firms that undertake product innovation is less dependent on the firm’s production efficiency in terms of labor productivity. On the other hand, efficiency in the production process seems to be crucial for firms’ geographical export expansion.

Moreover, the variables reflecting local concentration of exporters, multinationals and overall industry employment do not show any significant impact on the probability of export market expansion in either respect.

The results of the estimation of the selection equation (presented in the bottom of Table 5.8) show effects similar to those presented in Table 5.7; export market participation, permanent or occasional, in the previous period have a strongly significant impact on the probability of being a permanent exporter in the current period. Moreover, when the export status in the previous period is controlled for, other firm- and location-specific variables (except for the MNE dummy variables) have no significant impact on the export status in the current period. Still, affiliation with a domestic or foreign MNE significantly increases the probability of permanent export market participation.

In summary, the results in Table 5.8 provide some indications of learning-effects from previous export activities that stimulate exporting firms to expand their export activities both in terms of product scope and in terms of geographical diffusion. In accordance with previous estimations, the results in Table 5.8 indicate that firm-level variables, such as human capital intensity and labor productivity, stimulate firms’ export activities to extend to additional product varieties and to additional geographical destinations.
Table 5.8 Heckman selection estimations of probability of export market expansion

<table>
<thead>
<tr>
<th>Outcome equation (probability of export market expansion in period 2)</th>
<th>Introduction of new products</th>
<th>Entry on new geographical markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human capital intensity</td>
<td>1.0697*</td>
<td>0.9912</td>
</tr>
<tr>
<td>Labor productivity</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
<tr>
<td>Domestic MNE (dummy)</td>
<td>0.4220*</td>
<td>0.5121**</td>
</tr>
<tr>
<td>Foreign MNE (dummy)</td>
<td>0.3662*</td>
<td>0.5961**</td>
</tr>
<tr>
<td>Multi-market export in period 1 (dummy)</td>
<td>0.1564</td>
<td>0.7730**</td>
</tr>
<tr>
<td>Multi-product export in period 1 (dummy)</td>
<td>0.5956*</td>
<td>-0.1252</td>
</tr>
<tr>
<td>Local conc. of industry export</td>
<td>-0.0090</td>
<td>0.0468</td>
</tr>
<tr>
<td>Local concentration of MNEs</td>
<td>-0.0116</td>
<td>-0.0035</td>
</tr>
<tr>
<td>Local conc. of industry employ.</td>
<td>0.0346</td>
<td>-0.0056</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.7095*</td>
<td>-0.8179</td>
</tr>
</tbody>
</table>

| Selection equation (probability of permanent export status in period 2) | |
|---|---|---|
| Size | 0.0001 | 0.0001 | 0.0002 |
| Human capital intensity | -0.0246* | 0.4350 | 0.1868 |
| Labor productivity | -0.0004 | -0.0003 | 0.0002 |
| Domestic MNE (dummy) | 0.6571** | 0.7042** | 0.0968 |
| Foreign MNE (dummy) | 0.7918** | 1.7721** | 0.1304 |
| Local conc. of industry export | -0.0567 | -0.0544 | 0.0356 |
| Local concentration of MNEs | -0.0187 | -0.0110 | 0.0129 |
| Local conc. of industry employ. | 0.0747 | -0.0053 | 0.0880 |
| Permanent exporter in period 1 (dummy) | 2.7703** | 2.7785** | 0.0981 |
| Occasional exporter in period 1 (dummy) | 0.8134* | 0.7898** | 0.0902 |
| No. observations (censored obs.) | 3828 (1104) | 3828 (1104) |
| Wald χ² (29) (prob > χ²) | 247.04 (0.000) | 474.10 (0.000) |
| Wald test of independent equations: χ² (1) (prob > χ²) | 14.82 (0.000) | 106.65 (0.000) |

** Significant at the 1 % level, * Significant at the 5 % level. All Estimations include 2-digit industry dummies, not presented in the table.
A final comment on the Heckman selection probit estimations concerns the Wald test of independence between the selection and the outcome equation. This is a test of correlation in the error terms of the two equations, where the null-hypothesis is that \( \rho = \text{corr}(\eta_1, \eta_2) = 0 \). As indicated by the \( \chi^2 \)-values in the bottom row of Table 5.8, the null-hypotheses can be rejected, which implies that the probit regression with sample selection is preferable to a standard probit estimation.

6. Summary and Concluding Remarks

This paper addresses the importance of information and knowledge about foreign markets for firms’ export decisions. Theoretical and empirical literature explain variations in firms’ export behavior with the existence of export market entry costs. A substantial part of this fixed (sunk) investment originates from the necessity of having accurate knowledge about market conditions and business practices in various export destinations. This type of market knowledge is, to some extent, of an experiential type and accumulates in the individual firm through the process of penetrating foreign product markets. In this paper, it is argued that this knowledge is useful in the process of establishing additional product- and market-specific export links. Accordingly, there may be a learning-effect from penetrating foreign markets, which stimulates further export market expansion. Moreover, knowledge and information about foreign markets can be shared or spill over between firms and, therefore, this study also considers the influences of external knowledge on firms’ export behavior.

The empirical analysis of firms’ export behavior is based on discrete choice models, focusing on three types of export behavior. First, we consider the consistency in export status, distinguishing between firms that export permanently, occasionally or do not export at all over a period of 8 years. Second, the data are divided into two sub-periods such that we may observe changes in firms’ export status between periods. Of particular interest are firms that change from an occasional export status or non-export status in period 1 to a permanent export behavior in period 2. Third, we address the probability of firms expanding on export markets through introduction of new export products or establishment of new geographical export links.

The estimations include three types of variables: 1) firm-level characteristics 2) the firm’s export experiences in previous periods and 3) location-specific variables reflecting the potential for firms in a given location to benefit from
knowledge and information externalities. Summarizing the results, we focus separately on the three types of explanatory variables.

Firm characteristics in terms of size, labor productivity, human capital intensity and MNE affiliation increase the probability of a firm being a permanent exporter relative to the probability of exporting occasionally or not exporting at all. However, these firm-level variables do not seem to stimulate the probability of a firm changing its export status from non-export or occasional export to permanent export market participation, when the export statuses in previous periods are included among the regressors. Nevertheless, the labor productivity and MNE affiliation have a positive effect on the probability of a firm expanding its export activities to new geographical export destinations. For export expansion through introduction of new export products, the empirical results suggest that the crucial factor is human capital rather than labor productivity. One interpretation of these findings is that the competitiveness of firms that undertake product innovation is less dependent on the firm’s production efficiency, i.e., the labor productivity, whereas the production efficiency, on the other hand, is of significant importance for firms’ geographical export expansion.

Firms’ previous export experiences appear to have a strongly significant impact on current export decisions. Descriptive statistics reveal a strong persistence in export status over the two sub-periods considered in this analysis. Still, some firms do change export status and the results of the estimations of a binary probit model suggest that those firms that gather some experiential knowledge about foreign markets through occasional export in one period are more likely to become permanent exporters in the following period than firms that have no export experience in the first period. Moreover, a firm that has experiences from foreign markets in one period has a higher probability of expanding its export activities in the next period. These significant effects of previous export experience on current export decisions suggest that there may be learning-effects from export market participation that reduces the cost of establishing new permanent export links. The empirical estimations show that firms whose previous export experiences include many products and many markets are more likely to introduce additional products in their export sales. However, entry into new geographical markets seems to be less likely among firms that export many products to few markets, whereas export experience from many geographical markets stimulates further geographical expansion of export activities.

This empirical analysis also examines the influence of external spatial flows of knowledge and information on firms’ export decisions. The results show a
significant positive effect of the local concentration of firms exporting the industry’s commodities and of local concentration of the industry’s total employment on the probability of a firm exporting both permanently and occasionally. These results suggest that there are within-industry agglomeration economies that influence the export decision of the individual firm. There is, however, a possible endogeneity between these spatial concentration forces and the forces stimulating export market participation of the individual firm. This is an issue that must be addressed in further research, which should also target the possibility that such externalities exist across industries or operates over a larger spatial scale.
References


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Market experiences and export decisions in heterogeneous firms


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