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R&D ACCESSIBILITY AND COMPARATIVE ADVANTAGES IN QUALITY DIFFERENTIATED GOODS

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R&D Accessibility and Comparative Advantages in Quality Differentiated Goods

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Abstract

This paper analyzes the influences of human capital and technology transfers from R&D activities on regional export specialization along the range of product quality. Previous literature on specialization and trade in quality differentiated goods concludes that the production of high quality product varieties is intensive in knowledge and R&D. This study contributes to previous research by addressing the influence of spatial knowledge flows on the observed patterns of regional quality specialization. A theoretical model of endogenous quality choice derives regional comparative advantages to the presence of external knowledge flows from R&D activities. These knowledge transfers are modeled by accessibility variables, which deduce the presence of technology transfers from R&D activities to the geographical distribution of R&D activities and the observed patterns of spatial interaction. The impacts of regional R&D accessibility on regions' revealed comparative advantages in high quality segments are subsequently examined in a two-dimensional cross-regional regression analysis. The results of this empirical work show significant positive effects of human capital 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 increases the region's specialization in high-quality segments. These results are robust over four different specifications of above-average product qualities. However, the sizes of estimated coefficients for R&D accessibility rises slightly with the quality level considered. This suggests that technological advantages becomes of larger importance the more superior are the levels of product quality considered.

JEL: F12, F14, R12, R32

Keywords: Product quality, vertical differentiation, Knowledge, Accessibility, Spatial dependence, comparative advantage, technology

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1 Introduction

The influence of factor endowments and productivity differences on trade patterns have attained renewed interest since 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 main theoretical explanation to this type of trade is the same as for inter-industry trade, namely factor proportions and comparative advantages (Favley, 1981; Shaked and Sutton, 1984; Flam and Helpman, 1987; Favley and Kierzkowski, 1987; Davis, 1995). By the notation that factor proportions differ between goods of high and low qualities, dissimilarities in countries' factor endowments 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.

Empirical studies on trade in quality differentiated goods are generally 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 (Martìn and Orts, 2001; Chiarlone, 2000, Torstensson, 1991). The explanation to this observation is that industries' production technologies differ in factor intensities, implying that the national relative factor endowment creates comparative advantages for some industries and comparative disadvantages for others. Yet, cross-country differences in factor proportions or factor productivity cannot explain heterogeneity in product quality levels *within* industries in the same country. Observations from Swedish firm level export 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 that factor proportions or technological factors can explain vertical product differentiation, regional factor endowments or regional technology advantages should be of larger importance than national factors in explaining the position of the individual firm along the quality range.

This paper analyzes the importance of regional knowledge endowment and technology advantages on the revealed regional comparative advantages in production of high-quality goods. A specific attention is addressed to the importance of knowledge spillovers as a source of such comparative advantages. The hypothesis tested is whether regions with a relatively high share of highly educated workers (human capital) in manufacturing employment and good accessibility to R&D workers (technology advantages) have a larger share of high quality goods in manufacturing output than has the average region. This paper contributes to the existing literature in three ways. First, it addresses the issue of specialization and trade in quality differentiated goods on the regional 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 are fairly intensive in human capital, whereas vertical product differentiation, i.e. production of high quality products, appear to be more R&D intensive than production of low quality commodities (Faruq, 2006; Ferragina and Pastore, 2005; Martín and Orts, 2001; Chiarlone 2000). However, no previous study analyzes the impact of spatial knowledge flows on the pattern of specialization along the product quality spectrum. A third novelty in this analysis is the use of firm-level data instead of aggregate trade data in the assessment of product quality. Different product quality levels are identified by the conventional method of unit price comparisons, but in contrast to previous studies this analysis are based on firm-level unit prices rather than average prices calculated at aggregate product groups. The extensive variability in firm-level unit prices 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. Firm-level observations are subsequently used to calculate an index of regional revealed comparative advantage in high quality products. The influences of knowledge endowments and technological transfers from R&D activities on regional comparative advantages are then analyzed in a cross-regional regression analysis.

The importance of technology and innovation in explaining trade patterns was noticed already in the 1960s when theories on technology gaps and product life cycles were introduced by Posner (1961), Vernon (1966) and Hirsch (1967), among others. 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 et al. 2002; Barrios et al. 2003; Braunerhjelm et al, 2004; among others). Furthermore, 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 (Andersson, 1998; Coe et. a1, 1996; Grossman and Helpman, 1991; among others). The presence of localized knowledge spillovers induces a concentration of R&D activities to certain regions, which may play a fundamental role in shaping regional patterns of comparative advantage and subsequent trade specialization. Consequently, the "New Economic Geography"-framework emphasizes the role of the functional region rather than the nation (Johansson & Karlsson, 2001).

To my knowledge, there are no previous studies on the geographical distribution of production and export of quality differentiated goods within countries, yet several studies have analyzed the impact of regional R&D activities and knowledge spillovers on other aspects of regional export performance. Bresci and Palma (1999) present evidences of localized knowledge flows in Italian exports as they find that both exports and patenting activities in high-technology sectors is more spatially concentrated than is the manufacturing sector as a whole. Similar evidences on localized knowledge spillovers are found by Johansson and Karlsson (2007) when analyzing the impact of knowledge spillovers from R&D on regional export diversity. Gråsjö, (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 (2007) 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 regional export performance.

This analysis begins with a theoretical section, presenting a model where regional 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 cross-regional regression model used to test the hypothesis of a positive impact of regional knowledge endowments and technological transfers from R&D activities on regional comparative advantages along the quality range. The results of these estimations are presented and discussed in Section 4. Finally, Section 5 summarizes and concludes the outcomes of this analysis.

2 Theories of trade in quality differentiated goods

The analytical fundament of quality differentiation was introduced 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.

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. Fan (2005) points out that a geographical proximity to such demand also provides producers in such countries with a cost advantage in the supply of high quality product varieties. The majority of theoretical explanations to trade and specialization in vertical differentiated goods focus on pure supply-side factors. Falvey (1981) and Favely and Kierzkowski (1987) propose that differences in factor proportions are the driving forces behind vertical specialization. Several empirical studies confirms that the average quality level of export increases with per capita income, which is subsequently interpreted as an index of relative abundance of physical and human capital (Reganati and Pittiglio, 2005; Hummels and Klenow, 2002; Torstensson, 1991). Faruq (2006) find that the stock of physical capital stimulates the average quality in aggregate export flows. The significance of human capital effects on vertical specialization varies between different empirical studies. Ferragin 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.

Flam 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 product quality range. Davis (1995) argues that when the number of differentiated varieties is large there are excellent substitution possibilities across goods in production. In this case, small differences in production technology may have large impacts on firm-level profitability, which induce specialization and trade. Empirical support for 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 sectoral export flows from Spain increases with the amount of R&D spending. Moreover, the possibility of technology spillovers from multi-national enterprises have been examined by Faruq (2006) and Reganati and Pittiglio (2005) who finds 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 multi-national enterprises as disseminators of technological knowledge across national boarders (Ekholm, 2004; Keller and Yeaple, 2003; Blomström and Kokko, 1997; among others).

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).

The idea of comparative advantages arising from regional technology differences is formalized by Andersson (1998) in a model where the choice of product quality of the representative firm depends on the marginal productivity condition of the knowledge input necessary to produce high-quality goods. 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 the attributes in their own products. The aim of this process is to achieve some functional characteristics of the product that increase consumers' willingness to pay for it. Consequently, vertical product differentiation (likewise horizontal product differentiation) yields market power to the firm, which results in a market structure of monopolistic competition.

Andersson (1998) argues further that the firm-level input of human capital is not always sufficient to influence the consumers' willingness to pay for the firm's output because R&D and innovation has become much more global during the last decades The importance of external sources of knowledge as a complement to firms' internal knowledge, has been stressed also by (Malecki, 1997; Amin & 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 not 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 to the traditional theory of the firm, Andersson (1998) derives a marginal interactivity condition which relates the degree of interaction to the transaction cost of such interaction.

Following Andersson (1998) it is here assumed that the willingness to pay for a given commodity is a function of the firm's input of human capital and of the external knowledge absorbed and used in production. Hence, the market price (P_i) for a given product variety produced by the representative firm in region i is a function of the firms own input of knowledge, K_i, and of external knowledge flows from R&D activities in the own region and in all other regions I_{ji} (j = 1, …,n). Making the simplifying assumption that internal and external knowledge affect the quality level of output only, the quantity of output is simply a function of the input of low-skilled labor, L_i. The level of quality aspired by the individual firm is then endogenously determined by the firm's profit maximization conditions. The profit maximization problem of the representative firm i (located in region i) is formulated as:

$$\max \ \pi_i = P_i(K_i, I_{1i}, \ldots, I_{ni})Q_i(L_i) - r_i K_i - w_i L_i - \sum_j \tau_{ji} I_{ji} \qquad (1)$$

where *P(.)* and *Q(.)* are assumed to be concave, continuous and differentiable functions. *r* and *w* are the input prices of knowledge and labor respectively and τ_{ji} is the cost of interaction with economic agents in region j, i.e. the transaction cost of absorbing external knowledge from region j. The conventional marginal productivity conditions from this maximization problem are:

$$\frac{\partial \pi_i}{\partial K_i} = \frac{\partial P_i}{\partial K_i} Q_i - r_i = 0 \qquad (2.a)$$

$$\frac{\partial \pi_i}{\partial L_i} = P_i \frac{\partial Q_i}{\partial L_i} - w_i = 0 \qquad (2.b)$$

Equations 2.a and 2.b state that, conditional on factor prices, inputs of human capital and labor in region i depend on the marginal productivity of human capital, i.e. the economic efficiency of the innovation process, and the marginal productivity of labor, i.e. the efficiency of the production process. Equation 2.a implies that regional differences in the input price per efficiency unit of knowledge determine the optimal input of knowledge and thereby the quality level of output aspired by the representative firm located in a given region. If 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, on the other hand, factor markets are distorted by wage legislation, poor factor mobility or other institutional factors, factor prices may provide a basis for comparative advantages. Under those circumstances regions with a relatively low input price per efficiency unit of human capital will have a cost advantage in production of high quality products.

In addition to the conventional marginal productivity conditions, the optimal input of external knowledge is given by the marginal interactivity condition:

$$\frac{\partial \pi_i}{\partial I_{ji}} = \frac{\partial P_i}{\partial I_{ji}} Q_i - \tau_{ji} = 0 \qquad (3)$$

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 acquiring and implement such external knowledge. The transaction cost of external knowledge flows between two regions, τ_{ji}, is assumed to be an increasing function of geographical distance, i.e. travel-time distance, which reduces the efficiency in intra-regional and inter-regional interactions. This follows from the theoretical conjecture that new knowledge generated by R&D tends to be tacit or sticky in the sense that it is not codified. The diffusion of new knowledge is therefore largely dependent on interpersonal contacts, which frequencies 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 et al. 1999) among others). 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:

$$\frac{\partial P_i}{\partial I_{ji}} = R_j^{\gamma} I_{ji}^{-\lambda} \qquad 0 < \gamma < 1, \quad 0 < \lambda < 1 \qquad (4)$$

where R is the amount of R&D conducted in region j. The parameter γ reflects the technological relevance of these R&D activities for the production in region i and can be interpreted as an index of technological proximity. The parameter λ reflects the absorptive capacity of region i, which depends on the particular skills of labors and knowledge handlers employed in the region. Indeed, for new pieces of knowledge to be useful, the user must possess the relevant training and/or experience to fully grasp the implications of technological transfers from R&D activities (Lopez-Bazo et al; 2006; Massard, et al. 2005; Cohen, et al.1989). By using Equation 3 and 4, the knowledge flow from region j to region i can be written as:

$$I_{ji} = R_j^{\gamma/\lambda} Q_i^{1/\lambda} \tau_{ji}^{-1/\lambda} \qquad (5)$$

Equation 5 shows that knowledge transfers from region j to i increase with the amount of R&D in region j and with the quantity of goods produced in region i, 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:

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

where t_{ji} is the travel-time distance between the two regions and σ is a time-sensitivity parameter. The knowledge flow from region j to i is then approximated by:

$$I_{ji} = \left(R_j^{\gamma} \exp\{-\sigma t_{ji}\} Q_i\right)^{1/\lambda} \qquad (7)$$

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, $\left(R_j^{\gamma} \exp\{-\sigma t_{ji}\}_i\right)$, have the same properties as conventional accessibility measures, which have been frequently used as approximations of spatial spill over effects in recent empirical work (Johansson and Karlsson, 2007; Gråsjö, 2006; Andersson, Gråsjö and Karlsson, 2006; Ejermo, 2005; Niebuhr, 2003, among others).

The simple model of endogenous quality choice outlined above provides two explanations for regional comparative advantages to arise along the product quality spectrum. 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 advantage in the production of high quality goods because of lower costs of interaction, which intensifies spatial knowledge flows. The hypothesis that these two factors have a significant impact on the location of production and export of high-quality product varieties are tested in the sequel of this paper.

3 Empirical Methodology

The theoretical framework developed in section 2 predicts that regional variations in the input price of knowledge and the geography of external knowledge sources create comparative advantages along the product quality spectrum. This hypothesis is tested in a cross-regional regression model, estimated on the level of municipalities (local government areas). The analysis is based on a firm-level data set of Swedish export for the years 1999- 2003, which contains information about all firms' total export value and export volume at the 8-digit level of product classification. Furthermore, the location of the firm is defined at the municipality level, which gives 288 possible locations in Sweden. The variables reflecting R&D accessibility are calculated using an average of full-time equivalents worked in R&D activities in the private business sector and in university departments by persons holding an advanced university degree for the years 1993, 1995 and 1999. Moreover, 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.

Before testing the influence of knowledge and technology on regional quality specialization, a number of measurement issues are addressed in this section, which starts with a formal definition of accessibility followed by a presentation of the methodology used to define the quality level of export products. Section 3.3 defines the measurement of revealed comparative advantages and the empirical model used to test the hypothesis of this study.

3.1 Measuring R&D Accessibility

Knowledge spillovers from R&D are largely dependent on face-to face interaction, which is facilitated by geographical proximity. An accessibility approach is therefore particularly well suited in modeling spatial knowledge flows from R&D, because the accessibility reflects the choice context for spatial interaction (Weibull, 1976). The 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 by it's internal and external R&D milieu. 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 an advanced university 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:

$$A_i^R = R_i f(c_{ii}) + \ldots + R_n f(c_{in})$$

(8)

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:

$$f(c_{ij}) = \exp\{-\sigma t_{ij}\}$$

(9)

where the time-sensitivity parameter, *σ,* determines how the accessibility responds to changes in travel-times between regions, t_{ij} [1]. Combining Equations 8 and 9, region i's accessibility to R&D activities is defined as[2].

$$A_i^R = \sum_{j=1}^{n} R_j \exp\{-\sigma t_{ij}\}$$

(10)

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, 2006). 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 point where the main stream of interaction is shifted toward another region (Johansson, 1992). 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 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 *σ*, differs between local, intra-regional and inter-regional interactions (Johansson, et al. 2002) [3]. The three categories of R&D accessibilities are formally expressed as:

(i) Local accessibility: $AR_{Li} = \sum_{i \in S, S \in N} A_{iM}^R$, $A_{iM}^R = \exp\{-\sigma_1 t_{ii}\} R_i$

(11)

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

[2] A measure of accessibility should satisfy certain criteria of consistency and meaningfulness. The measure used here satisfies those warranted criteria, derived by Weibull (1976).

[3] 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).

(ii) Intra-regional accessibility: $AR_{Ii} = \sum_{i\in S,} A_{iS}^{R}$, $A_{iS}^{R} = \sum_{j\in S,\ j\neq i} \exp\{-\sigma_2 t_{ij}\} R_j$ (12)

(iii) Inter-regional accessibility: $AR_{Xi} = \sum_{i\in N} A_{iX}^{R}$, $A_{iX}^{R} = \sum_{r\notin S} \exp\{-\sigma_3 t_{ik}\} R_k$

(13)

Equations 11, 12 and 13 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, S, and the inter-regional accessibility is the municipality's accessibility to R&D facilities in all locations outside region S. Equations 11-13 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. As such, 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. Gråsjö (2006) suggests that significant estimated effects of accessibility variables can be interpreted as evidences of spatial dependencies. The inclusion of accessibility variables therefore significantly reduces spatial auto-correlation.

3.2 Defining quality

In the literature of international trade quality differences are presumed to be reflected by differences in unit values (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 consumers' willingness to pay for a given variety and with perfect information, consumers are willing to pay more for varieties that yield higher utility[4].

A common method for approximating product quality in trade data is comparisons of averages 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

[4] 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 if information is imperfect.

refers to product groups. Firms' export prices are compared to the average import price of varieties in the same product group according to the formula:

$$\frac{P^{X}_{k\in G}}{\overline{P}^{M}_{G}} \leq 1+d \qquad (14)$$

The numerator in equation 14 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 differentials between varieties of average quality and varieties of higher qualities. A variety that has an export price that exceeds the average import price in the relevant product group by a certain percent is defined as a high quality product. Different values of the price dispersion factor have been used to distinguish high quality products in previous empirical research. At the purpose of investigating the robustness of the empirical results to different specifications of high-quality goods, this analysis applies four different values of the price dispersion factor: 0.1, 0.25, 0.5 and 1. Moreover, aggregation biases have been minimized by defining unit values 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 have been calculated with respect to import from the EU countries only.

3.3 Empirical Model

The concept of comparative advantages 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 advantages was introduced by Balassa (1966) and uses regions' relative market shares as an indicator of comparative advantages. A variant of the conventional Balassa-index is presented by Hoen and Oosterhaven (2006) who propose a deviation from mean approach in measuring revealed comparative advantages (RCA). Their measure of RCA is here applied on regional specialization in vertically differentiated goods. In this context the RCA index 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 focus on the pattern of location of high quality goods in Sweden the share of high quality goods in the aggregate Swedish export flow is used as reference. The measure of revealed comparative advantage in region *i* is calculated according to:

$$RCA_i^H = \left(V_i^H / V_i\right) - \left(\sum_{j \neq i} V_j^H / \sum_j V_j\right)$$

(15)

where $V_i^H = \sum_G \sum_{k \in G} P_k^X Q_k^X I_k$, $I = \begin{cases} 1 \ if \ \left(P_{k \in G}^X / P_G^M\right) > 1 + d \\ 0 \ otherwise \end{cases}$

and $V_i = \sum_G \sum_{k \in G} P_k^X Q_k^X$ $\forall k$

This measure of RCA, which has the properties of a symmetric distribution and a mean value of zero, 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.

The hypothesis of a regional export specialization along the quality range, dependent on knowledge input and R&D accessibility is tested on a two-dimensional data set, which defines revealed comparative advantages across regions and sectors. The industry dimension is controlled for by 2-digit industry dummies. The two-dimensional cross-regional regression model is specified accordingly:

$$RCA_{is}^H = \alpha + \beta_1 K_{is} + \beta_2 AR_{Li} + \beta_3 AR_{Ii} + \beta_4 AR_{Xi} + \beta_5 MNE_{is} + \beta_6 S_{is} + \beta_7 M_i + \delta_n D_s + \varepsilon_{is} \qquad (17)$$

where the dependent variable is the revealed comparative advantage in high-quality production of municipality i and sector s. K_{is}, reflects the input of human capital (number of employees with at least three years of university education) in sector s in region i. AR_{Li}, AR_{Ii} and AR_{Xi} are the accessibility variables, defined in Equations 11-13, which reflect the flows of external knowledge generated by R&D. The R&D data available for this study are not disaggregated to the level of sectors, for what reason the accessibility variables are defined across municipalities only. Consequently, the aspect of sectoral technological spillovers and the role of technological proximity have to be excluded from this study. The variable MNE_{is} is the share of export accounted for by multinational firms, which provides a measure of potential knowledge transfers from foreign countries (Faruq, 2006; Keller and Yeaple; 2003; Blomström and Kokko, 1997).

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 manufacturing sector. This variable is defined as the municipality's share of the total sector employment, S_i. Moreover, the variable M_i controls for the size of the total manufacturing sector in the municipality in terms of the share of manufacturing employment in total municipality employment. D_s is a vector of dummy variables controlling for sector heterogeneity. Finally, ε_i is the error term following the usual assumption of zero mean and constant variance. The definitions of the explanatory variables are summarized in table 1.

Table 1 Explanatory Variables

Variable Name	Description	Definition
K_{is}	Human Capital	Number of employees in industry s in region i with at least three years of university education.
AR_{Li}	Local accessibility to R&D	The amount of R&D conducted within municipality i, weighted by the travel time distances within the municipality.
AR_{Ii}	Intra-regional Accessibility to R&D	The amount of R&D conducted in other municipalities within the labor market region of municipality i, weighted by a time-travel distance matrix.
AR_{Xi}	Inter-regional Accessibility to R&D	The amount of R&D conducted in municipalities outside the labor market region of municipality i, weighted by a time-travel distance matrix.
MNE_{is}	Presence of multinational firms	Share of the total export value from sector s in region i that is exported by a multinational firm.
S_{is}	The relative size of the sector	The municipality's share of total employment in sector s
M_i	Regional size of the total manufacturing sector	Manufacturing share of total municipality employment.

4 Empirical Results

The theoretical framework presented in Section 2 advocates that regional export specialization along the quality spectrum is positively dependent on the input of human capital, input of external knowledge from R&D (R&D accessibility) and technological spillovers from multinational firms. It is certainly the case that the importance of human capital and external knowledge flows from R&D activities differs between product groups, industries and broad sectors. However, the R&D data used in this study are not disaggregated to the level of sectors, for what reason the aspect of sectoral technological spillovers and the role of technological proximity have to be excluded from this study.

For the total manufacturing sector, the share of high quality goods in total manufacturing export varies depending on the definition of quality. Table 2 presents descriptive statistics of the share of high quality export in total regional export of manufactured goods $\left(V_i^H / V_i\right)$ according to the four different values of the price dispersion factor in Equation 14. The larger is this dispersion factor, the larger is the price differential between exported and imported product varieties, which implies that the higher is the quality of the exported product variety relative to imported varieties. The third column in Table 2 shows that the average share of high-quality goods in Swedish export varies with the value of the dispersion factor used for identify high quality commodities. Explicitly, the mean share of high quality goods in regional manufacturing export 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 almost 54 percent of regional export in average (first row in Table 2). Varieties with an export price that is twice as large as the corresponding import price only accounts for 24.67 percent of regional export in average (last row in Table 2). The minimum and maximum values of $\left(V_i^H / V_i\right)$ follows the same pattern and decreases with the value of the dispersion factor. Still, these figures indicate that there are large variations in the regional degree of specialization in high quality products, independently of the value of the dispersion factor.

Table 2 Percentage share of high-quality export in total municipality export

	Minimum	Maximum	Mean	St. Deviation
Percentage share of export value consisting of products with $P_{k\in G}^X / P_G^M > 1.1$	2.25	99.04	53.97	23.74
Percentage share of export value consisting of products with $P_{k\in G}^X / P_G^M > 1.25$	0.89	94.69	45.62	23.83
Percentage share of export value consisting of products with $P_{k\in G}^X / P_G^M > 1.5$	0.05	92.71	35.50	23.30
Percentage share of export value consisting of products with $P_{k\in G}^X / P_G^M > 2$	0.04	90.94	24.67	19.86

The shares of high quality goods in total regional export $\left(V_i^H / V_i\right)$ are used to construct the index of revealed comparative advantage according to Equation 15. Table 3 presents descriptive statistics of the revealed regional comparative advantage (the dependent variable in the cross-regional regression model). By definition, the mean value is zero, which is interpreted such that the average region has no advantage or disadvantage in production of high quality goods. The medium deviates from zero, but as the figures in Table 3 reveals, this deviation is fairly small, which indicates that the distribution of the regional RCA index becomes more skewed the higher is the quality level considered. 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). This indicates that variations in the regional specialization along the product quality spectrum are more pronounced the higher are the quality levels considered.

Table 3 Municipality Revealed Comparative Advantage in production of high-quality goods.

	Minimum	Maximum	Median	St. Deviation
RCA 1: High quality products are defined as varieties with $P^X_{k\in G} / P^M_G > 1.1$	-0.52	0.45	0.01	0.24
RCA 2: High quality products are defined as varieties with $P^X_{k\in G} / P^M_G > 1.25$	-0.45	0.49	-0.05	0.24
RCA 3: High quality products are defined as varieties with $P^X_{k\in G} / P^M_G > 1.5$	-0.36	0.57	-0.04	0.23
RCA 4: High quality product are defined as varieties with $P^X_{k\in G} / P^M_G > 2$	-0.25	0.66	-0.04	0.20

Descriptive statistics of the independent variables of the model specified in Equation 17 is presented in Table 4. Of particular interest in this table are the figures of the variables human capital, R&D accessibility and MNE's share of municipality export which show a highly skewed distribution. This implies that the assumption of homoscedastic error terms is likely to be violated. The Breusch-Pagan test indicates heteroscedasticity for what reason the White's robust covariance matrix has been used to adjust the standard OLS estimates

Table 4 Descriptive Statistics of Explanatory Variables

	Minimum	Maximum	Mean	St. Deviation
Human Capital	0.00	5599.20	16.62	131.36
Local Accessibility to R&D	0.00	3656.06	60.86	355.76

Intra-regional Accessibility to R&D	0.00	2373.70	134.38	349.04
Inter-regional Accessibility to R&D	0.00	1081.51	110.38	179.82
MNE's share of Export	0.00	1.00	0.02	0.06
Municipality share of total sector employment	0.01	0.32	0.06	0.01
Share of manufacturing employment in total municipality employment	0.05	0.19	0.16	0.02

The hypothesis of a positive impact of human capital and technological spillovers from R&D activities and multinational firms on regional revealed comparative advantages is tested through estimations of the two-dimensional cross-regional regression model in Equation 17. All variables, but the accessibility variables and the size-variable for the total manufacturing sector, are defined at the two-digit industry level in each region. With these properties, the data set contains 4146 sector-region specific observations. The sector dimension is controlled for by inclusion of industry dummies. Moreover, the regression model is applied on the four different specifications of the dependent variable with the objective to investigate the robustness of the empirical results.

The empirical results of the regression analysis, presented in Table 5, indicate that the human capital variable has a significant positive effect on regional RCA in all four specifications of the RCA index. The size of the estimated coefficient does not change substantially over the four different estimations, which is consistent with previous empirical findings suggesting production of differentiated varieties of all qualities to be fairly intensive in human capital.

The results reported in Table 5 further reveal that regional variations in the degree of high-quality specialization are significantly influenced by knowledge flows from R&D, approximated by the accessibility variables. Both local and intra-regional R&D accessibility have a positive impact on the regional revealed comparative advantage in production of high quality goods. This finding is robust over the four different definitions of high-quality goods, yet the estimated values of the regression coefficients increase slightly with the dispersion factor applied in calculating the RCA index. This outcome signifies that the importance of technological transfers from R&D is amplified the higher is the product quality level considered. Moreover, the influence of intra-regional R&D accessibility on regional quality specialization seems to be stronger than the local R&D accessibility. This outcome is likely driven by the fact that many municipalities in Sweden do not host any R&D activities within its boarders. For these municipalities, the external knowledge geography is all that matters.

The estimated coefficients for inter-regional R&D accessibility are positive but only significant in the second and third regression. The less robust verifications of presence of inter-regional knowledge flows adhere to a large body of previous empirical evidences of the importance of geographical proximity for spatial knowledge flows to be influential. However, the variable reflecting spillovers from foreign knowledge sources, MNE's share of regional export, shows a significant and positive effect on the regional revealed comparative advantage in high quality export. As with the human capital variable, there are no clear indications of an increased influence of MNE's for the most superior quality segments, as the size of the estimated regression coefficient is reasonably robust over the four specifications of the RCA index.

Table 5 Impact of Human Capital and Technological Spillovers on Regional Revealed Comparative Advantages

Dependent Variables / Explanatory Variables	RCA 1 High quality products defined as varieties with $P^X_{k\in G}/P^M_G > 1.1$	RCA 2 High quality products defined as varieties with $P^X_{k\in G}/P^M_G > 1.25$	RCA 3 High quality products defined as varieties with $P^X_{k\in G}/P^M_G > 1.5$	RCA 4 High quality products defined as varieties with $P^X_{k\in G}/P^M_G > 2$
Constant	**0.094 (2.43)**	**0.112 (2.71)**	**0.116 (2.69)**	**0.974 (2.21)**
Human Capital	**0.187E-03 (3.42)**	**0.219E-03 (4.12)**	**0.221E-03 (3.35)**	**0.199 (3.13)**
Local R&D Accessibility	**0.217E-04 (2.34)**	**0.219E-04 (2.39)**	**0.281E-04 (2.82)**	**0.289E-04 (2.85)**
Intra-regional R&D Accessibility	**0.439E-04 (3.80)**	**0.494E-04 (4.05)**	**0.644E-04 (5.17)**	**0.656E-04 (5.20)**
Inter-regional R&D Accessibility	0.493E-04 (1.94)	**0.742E-04 (2.89)**	**0.616E-04 (2.34)**	0.424E-04 (1.59)
MNE's share of Export	**0.105 (2.30)**	**0.118 (2.52)**	**0.131 (2.72)**	**0.119 (2.13)**
Municipality share of total sector employment	**-2.037 (-2.99)**	**-2.545 (-3.74)**	**-2.976 (-4.29)**	**-3.025 (-4.59)**
Share of manufacturing employment in total municipality employment	**-0.590 (-2.59)**	**-0.736 (-3.10)**	**-0.778 (-3.13)**	**-0.649 (-2.58)**
F-value (significance)	3.63 (0.000)	4.27 (0.000)	4.71 (0.000)	3.92 (0.000)

Bold figures indicate significance at the 5-percent level. t-values within parenthesis.

The theoretical model of endogenous quality choice predicts that input of human capital and external knowledge flows is more beneficial the larger is the scale of production. The variable controlling for the relative size of the sector shows a significant negative effect on the regional revealed comparative advantage in high-quality goods. 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. Because of smaller production scales in production of high quality varieties, the size variable shows a significant negative effect on regional quality specialization. This negative influence seems to be stronger the more advanced is the quality segment considered. Another indication from the regression results in Table 5 is that the more important is the aggregate manufacturing sector in total municipality employment the less specialized is the region in production of high-quality goods. This follows from the estimated negative sign of the variable showing the share of manufacturing employment in total municipality employment. A plausible explanation to this outcome is poor accessibility to producer services and human capital in service sectors in municipalities where large scale manufacturing industries dominates employment.

A final comment on the results presented in Table 5 concerns the significance of the cross-regional regression model. The F-values in the bottom row in Table 5 show that the regression model is significant in all four estimations, but performs better in the cases where the RCA are defined for higher quality segments (column 3 and 4). 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 size of the regression coefficients of local and intra-regional R&D accessibility increase with the price dispersion factor used to define the RCA index. This tendency signifies that knowledge flows from R&D has a stronger influence on revealed regional advantages in the most advanced quality levels.

5 Summary and Concluding Remarks

Theoretical and empirical literature suggests that specialization and trade in quality differentiated goods depend on comparative advantages originating from differences in human capital endowment and/or differences in technological knowledge. By the notation that high quality goods are more intensive in human capital and in R&D, countries and regions seem to specialize in different segments along the product quality spectrum. However, empirical studies in this field are generally conducted at the level of nations, which cannot appropriately explain firm-level variability in quality levels across products belonging to the same narrowly defined product group. At the purpose of analyzing the influence of location-specific factors on the quality of exported goods, this paper examines the impact of human capital and technology advantages on regional comparative advantages in production of high quality varieties. The data used for this cross-regional analysis is aggregated from firm-level trade data, which minimizes aggregation biases in the approximation of product quality.

The theoretical model applied derives regional comparative advantages in high quality goods to regional differences in factor costs and to regional variations in accessibility to R&D activities. These accessibilities are presumed to capture the importance of external knowledge flows from R&D activities within the own regions and in surrounding regions. As such, this theoretical framework emphasizes the role of technological transfers from R&D in generating regional technology advantages.

The empirical analysis focuses on the impact of regional human capital and spatial knowledge flows from R&D activities on the revealed regional 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 human capital input and knowledge transfers from R&D activities in Swedish municipalities, the empirical model also considers the influences of multinational firms, which may play the role of disseminators of technological knowledge from abroad. The regression model is applied on four different specifications of the dependent variable, revealed comparative advantages, corresponding to four different definitions of high quality products.

The empirical results indicate significant positive effects of technological transfers from R&D conducted at the local level (municipality) as well as from R&D efforts in other municipalities within the 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 of the regression coefficients increases slightly with the product quality level, which suggests that technological spillovers from R&D becomes increasingly important the higher is the quality level considered. The inter-regional accessibility to R&D, presumed to capture the presence of knowledge flows from locations outside the own functional region, does only show a significant positive effect in two of the four specification of revealed comparative advantages. This outcome supports previous empirical evidences of the role of geographical proximity for knowledge spillovers to emerge. Furthermore, the presence of multinational firms seem 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, which supports the hypothesis of international technology transfers through multinational firms (Faruq, 2006).

Moreover the variable for human capital input (employees with at least three years of university education) show a significant positive impact on the revealed regional specialization along the product quality range. There is no obvious tendency of an increased size of the estimated regression coefficients of this variable for more superior quality levels. This finding suggests that production of differentiated varieties of all above-average qualities is intensive in human capital. This result is consistent with empirical results from cross-country analyses, which report weak significance of human capital variables along with relatively strong influences impacts of R&D activities (Faruq, 2006; Ferragin and Pastore, 2005; Martín and Orts, 2001). 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 regional 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 to quality competitiveness of firms, regions and nations. How these relationships vary over industries and firms is an important issue for further research.

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