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Variety and Quality in Intra-European Manufacturing Trade: The Impact of Innovation and Technological Spillovers

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Abstract

Recent analysis of detailed product-level trade data points to substantial heterogeneity in variety and quality patterns in international trade. We study the evidence of variety and quality of manufacturing trade among European Union countries. The existing methodology is extended by distinguishing between various industrial sectors. In particular we focus on the role of technological innovation and technological spillovers. Although the impact of technological innovation depends on the innovation measure used, there appears to be a quality-upgrading effect originating from innovation. Moreover, technological spillovers increase both the variety and quality of intra-European trade.

Keywords: international trade, quality, variety, unit values, extensive margin, intensive margin

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1. INTRODUCTION

The variety and quality of products is at the core of international trade theory. Trade theories assuming imperfect or monopolistic competition recognize their importance in determining the direction and volume of trade. Despite this theoretical relevance, empirical insights into the patterns of variety and quality of international trade are scarce. This is to a large extent due to a lack of well-defined empirical tools for the measurement of variety and quality of trade, in combination with unavoidable immense data computation work. Nevertheless, a better understanding of the role and determinants of variety and quality is useful. It may help us improve existing trade theories that often fail to endogenize quality and variety. Moreover it provides insights into how quality upgrading or variety expansion may affect countries' or firms' performance and policy.

In this paper we will study the evidence of variety and quality of trade among European Union member states. New trade theory predicts that countries produce and export different varieties of goods. These varieties can be differentiated either horizontally (by characteristics) or vertically (by quality). Several authors have recently used very detailed (sectoral or product-level) export data to study the empirical evidence regarding the variety and quality of international trade, including a search for determinants of both variety and quality. This paper adds more empirical evidence to the existing literature. It is innovative first by exclusively focusing on the European Union, secondly by extending the existing methodology and finally by taking into account the role of technological innovation and spillovers as determinants of variety and quality of trade.

In order to study the importance of variety and quality in trade flows, total trade values are decomposed into variety and quality components. This can be done in several ways. One popular approach is to calculate intensive and extensive margins. A higher value of a nation's export can be the result of either a higher quantity and/or a higher price of exported products (the intensive margin), or of a higher number of varieties exported (the extensive margin). On the one hand, an increase in the extensive margin indicates an increase in the role of variety. An increase in the intensive margin, on the other hand, reflects further and successful specialization in

the production of existing varieties. The intensive margin can further be decomposed into a quantity and a price component. Higher export prices, mostly proxied by export unit values (export value divided by export volume), are regarded as evidence for higher quality.

Recent empirical evidence points to considerable heterogeneity in variety and quality patterns in international trade (e.g., Schott (2004), Hummels and Klenow (2005), Kaplinsky and Santos-Paulino (2005), Broda and Weinstein (2004)). Once variety and quality are measured, one can look for explanations for observed variety- and quality-patterns. The majority of studies look into price differences (hence quality differences), but the interest in determinants of variety has recently increased as well. Schott (2004) shows that unit values of U.S. manufacturing imports from different trading partners vary widely even within very detailed product categories. U.S. import unit values are systematically higher for varieties originating in capital- and skill-abundant countries compared to those from labour-abundant countries. More capital-intensive techniques also cause higher export prices. Finally, over time capital- and skill-deepening countries experience an increase in unit values relative to the countries that they leave behind. Hummels and Klenow (2005) extend Schott's findings to more exporting countries and more import markets. Using 1995 trade data for 126 exporters for 59 import markets, Hummels and Klenow study the relationship between country size and variety and quality patterns using a decomposition into extensive and intensive components. There appears to be a large degree of heterogeneity among exporters in their extensive and intensive margins. It appears that it is particularly larger countries that export more as they export more varieties. This finding implies that the extensive margin is more important in larger economies' export patterns. Moreover country size has a bigger impact on the quantity component than on the price/ quality component of the intensive margin, although prices are positively influenced by exporter size and income too. Hence larger and richer countries export more units of the same varieties at modestly higher prices, equivalent to modestly higher quality exports. Kaplinsky and Santos-Paulino (2005) find evidence that, based on a study of the evolution in unit values of imports into the European Union countries in a selected number of disaggregated manufacturing sectors, unit-price trends vary with the type of economy exporting into the European Union and the type of product being exported. Low-income countries show in the

period 1988-2002 a decline in their export prices for the European Union market, pointing to intense competition in the markets that they operate in. At the sectoral level, higher technological content appears to be a protection against falling export prices in the European Union.

Most of these arguments are supply-side determinants. However, demand-side explanations have also been formulated, inspired by the Linder-hypothesis (1961). Several theoretical (general equilibrium) models have formalized the Linder hypothesis or related arguments (e.g., Falvey and Kierzkowski (1987) and Stokey (1991)). Flam and Helpman (1987) develop a formal model with North-South trade. Quality is part of the individual's utility function. Assuming that richer countries have a comparative advantage in producing high-quality goods, the overlap of income distributions between north and south is shown to be a source of trade. Several authors extend the Flam-Helpman model using income differences as a source of trade between poor and rich countries (e.g., Copeland and Kotwal (1996) and Murphy and Shleifer (1997)). More recently, Fajgelbaum et al. (2009) have developed a model that shows how income distributions affect the quality of products and hence the trade pattern. Also recently, Fan (2004, 2005) has developed a model with a combination of economies of scale and different quality preferences. He formally shows that this combination explains the observed trade patterns of intra-industry trade. Sutton (2007) models mechanisms of quality-upgrading in traded goods because of international liberalization. Focusing on recent empirical work, Hallak (2005) develops a framework to estimate the impact of quality on bilateral trade. His results confirm the role of demand-side elements as richer countries tend to import relatively more from countries that produce high-quality goods. Also Funke and Ruhwedel (2001) conclude that per capita income positively affects both exports and imports across 19 OECD countries.

To summarize, many recent studies point to heterogeneity in the varieties and quality traded by countries. For the explanation of differences in export prices, hence for differences in quality of traded products, both demand-side and supply-side arguments have been formulated and tested. The literature hence clearly shows that importer's and exporter's income and size are important determinants of both variety

and quality patterns. In addition, factor proportions contribute to the explanation of observed international export price differences.

In this study, we focus on 11 member states of the European Union¹. Apart from mapping the respective importance of variety and quality in European trade, we attempt to explain these patterns. The European Union is an interesting group of countries to study variety and quality of trade for several reasons. First, the European market is a customs union. Hence the pattern of variety and quality will not be affected by barriers to trade, such as tariffs, quotas, etc². Secondly, the European Union is much more than a customs union, namely an integrated market. Within this integrated market several policies have been harmonized or transferred to the European level leading to a situation of fair competition among the member states (e.g., common European competition policy). Given this market situation, firms within the European Union market compete, much more than in other parts of the world, based on their real comparative advantages without being protected by discriminating barriers to trade. This implies that price differences for similar products, more than elsewhere, reflect differences in quality³. Hence we are more confident in interpreting our findings about price differences as evidence about quality differences. Nevertheless the European Union is a heterogeneous group of countries. They differ in their characteristics (size, income, geographical location,...), but also in their economic structure, reflected in different sectoral specialization patterns. This motivates the current analysis focusing on the impact of country and sectoral characteristics. In order to study the determinants of variety and quality in intra-European trade flows, we opt for a specific approach. Following Hummels and

¹ These countries are Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom. Of the EU15 countries Luxembourg, Portugal, Greece and Austria have been excluded because of data limitations (see data section).

² However, recent evidence indicates that trade policy may affect the speed of technology adoption of firms, which can result in higher productivity (see Konings and Vandenbussche (2007) for European Union evidence based on antidumping). Hence in sectors subject to European Union antidumping policy the intra-European trade pattern may be affected. Unfortunately the antidumping data are scarce. Therefore it is hard to find any evidence based on some general analysis. This is a very interesting subject for future research.

³ Gil-Pareja and Sosvilla-Rivero (2004) show that export-price dispersion across European Union countries is smaller than across OECD countries. In addition, export price convergence is larger in the European Union. This evidence can be considered as an indication that the European market is relatively highly integrated.

Klenow (2005), we adapt Feenstra's (1994) definition of extensive and intensive margins. We further decompose the intensive margin into a quantity and price/ quality component. Similar to most earlier studies we use very disaggregated export data to calculate each of these trade components. Similar to Hummels and Klenow (2005) we also focus on bilateral trade among a selected group of countries instead of focusing on a single market (like e.g., Schott (2004) for the U.S.). However, by focusing on European Union countries we select a group of countries with fewer trade distortions when trading with each other. Unlike these related studies we want to take into account other determinants of variety and quality. In particular we are interested in the role of technology-indicators, both country-level and sector-specific indicators. Determining the role of sectoral characteristics for variety and quality of trade is not straightforward. Given the detailed level of export data it is impossible to relate at such detailed level variety and quality evidence to sectoral characteristics. Unfortunately such detailed product characteristics are not available. Therefore we have to construct sectoral indicators of quality and variety based on the product-level information for all products belonging to the sectors defined. We distinguish between 22 industrial sectors, defined by the ISIC revision 3 classification.

We investigate the role of technological performance as a determinant of variety and quality of intra-European trade, controlling for the determinants found in earlier studies. There is extensive evidence in the literature that technological performance improves export performance (e.g., Grossman and Helpman (1991, 1995), Murphy and Shleifer (1997)). We investigate whether this is reflected also at the product level, and whether technological performance increases either the number of varieties exported, or the quality of traded varieties. Good export performance, either reflected by the export of new varieties or by a successful specialization in existing varieties, can be the result of a comparative advantage in the production of these goods. By focusing on technological performance, we study whether technological innovation can be the source of such comparative advantage. However, we do not limit our analysis to domestic innovation efforts only. We will also investigate whether international technology spillovers have an impact on variety and quality of trade. In order to do so we will measure the extent of technology spillovers among European Union countries, either through the trade or the foreign direct investment channel.

Apart from case studies for particular sectors or products, there is not much evidence about the relationship between trade and technology based on data at the product level. Notable exceptions are Anderton (1999) and Frensch and Wittich (2009). Anderton (1999) shows that disaggregated German and British imports are affected by innovation, quality and variety. Nevertheless Anderton does not directly relate quality and variety to innovation. Recent work by Frensch and Wittich (2009) finds a close relationship between variety in traded capital goods and technical change.

The remainder of this paper is structured as follows. Section 2 discusses the decomposition methodology in order to measure variety and quality. Some evidence regarding quality and trade in intra-EU manufacturing trade is discussed in Section 3. Section 4 contains the empirical estimation methodology and some data issues. In Section 5 we discuss the results from the analysis of the determinants of variety and quality of intra-EU trade. In particular we focus on the impact of innovation and technological spillovers. Section 6 concludes.

2. MEASUREMENT OF VARIETY AND QUALITY OF INTERNATIONAL TRADE

Several measures of variety and quality of traded goods have been used throughout the empirical trade literature⁴. A distinction can be made between — on the one hand — empirical methodologies that decompose total trade flows into a variety and a quality component and — on the other hand — ad hoc indicators of variety and/or quality (these include e.g., just counting the number of varieties). In the latter category those indicators measuring variety of trade clearly outnumber quality indicators. It is clear that quality is a more difficult concept than variety, although both are defined in various ways. As a result more efforts have been put into the analysis of variety of trade than into the study of quality of trade. Nevertheless both are worth intensive study. Even the ad hoc indicators are not easily comparable. A

⁴ We do not discuss the welfare effects of variety and quality of trade, although several authors showed that variety and quality matter for overall welfare (see e.g., Hausman (1981), Feenstra (1992), Romer (1994), Klenow and Rodriguez-Clare (1997), Broda and Weinstein (2006), Arkolakis et al. (2008), Feenstra and Kee (2008)).

variety is typically defined as the homogeneous output of one particular firm (in the event of product differentiation). Since in practice multi-product firms are not uncommon, and firm-level evidence regarding the produced varieties is largely unavailable, a firm-level approach to computing the overall importance of variety — although preferable — is almost always impossible. Instead one therefore mostly looks at very disaggregated trade statistics. A decomposition methodology clearly outperforms simple ad hoc indicators.

Based on the seminal work of Feenstra (1994) and Feenstra and Lee (2004), one can decompose total trade flows into a variety and a quality component. Several authors have implemented and further developed this methodology. It consists of splitting up total bilateral export flows into an extensive and an intensive margin of trade, and the latter further into quantity and quality components. Hummels and Klenow (2005) use this decomposition technique to compute the relative importance of variety and quality for 126 exporters and 59 importers in 1995. Their evidence points to large levels of heterogeneity in both the extensive and the intensive margin. This finding extends Schott's (2004) finding that US import unit values vary widely even within very detailed product categories. The decomposition methodology proceeds as follows⁵: for each import market m the extensive margin for sector i , composed of varieties (or products) k (with quantity x and price p), from exporter country j to importing country m (both j and m are European Union member states) is equal to

$$EM_{jmi} = \frac{\sum_{k \in K_{ijm}} p_{lmik} x_{lmik}}{\sum_{k \in K_{ilm}} p_{lmik} x_{lmik}} \quad (1)$$

K_{ijm} is the set of observable products within sector i in which country j has non-zero exports to country m , hence $x_{jmik} > 0$. The entire European Union (EU-15), denoted by l , is used as reference "country". Hence K_{ilm} is the set of observable products within sector i in which the European Union has non-zero exports to country m during

⁵ We are here already adapting Feenstra's methodology to the intra-EU context we will focus on in the next sections.

the period observed. According to this definition the extensive margin can be interpreted as the weighted number of varieties exported by country j to country m relative to the total weighted number of varieties exported by European Union countries to country m . The varieties are weighted by their importance in European Union exports to country m ⁶.

The corresponding intensive margin is equal to

$$IM_{jmi} = \frac{\sum_{k \in K_{ijm}} p_{jmik} x_{jmik}}{\sum_{k \in K_{ilm}} p_{lmik} x_{lmik}} \quad (2)$$

The intensive margin hence measures the export market share of country j in total European Union exports to country m in those varieties which j exports to m . Note that the total market share in sector i of country j in total intra-European exports is equal to the product of the extensive and intensive margins, i.e.

$$EM_{jmi} IM_{jmi} = \frac{\sum_{k \in K_{ijm}} p_{jmik} x_{jmik}}{\sum_{k \in K_{ilm}} p_{lmik} x_{lmik}} \quad (3)$$

The intensive margin can further be decomposed into a quantity and a price (quality) component. For each sector i and each import market m , we construct a price index based on a weighted average of the export price of country j 's varieties in market m relative to the average export price of European Union exporters' varieties in market m . This price index is equal to

⁶ As Hummels and Klenow argue, this approach has the advantage that no bias can be caused by products mainly (or only) exported by a single European Union country to country m . The disadvantage is that the extensive margin can be large because a single country exports a small amount of many varieties in which the entire European Union exports a lot. Since Hummels and Klenow do not find evidence for the latter, the disadvantage is not likely to affect the results.

$$P_{jmi} = \prod_{k \in K_{ijm}} \left(\frac{p_{jmik}}{p_{lmik}} \right)^{w_{jmik}} \quad (4)$$

These relative prices are weighted by w_{jmik} , equal to the logarithmic mean of s_{jmik} (the share of variety k in country j 's exports to m in sector i) and s_{lmik} (the share of variety k in European Union exports to m in sector i , where $k \in K_{ijm}$), or

$$s_{jmik} = \frac{p_{jmik} x_{jmik}}{\sum_{i \in K_{ijm}} p_{jmik} x_{jmik}} \quad (5)$$

$$s_{lmik} = \frac{p_{lmik} x_{lmik}}{\sum_{i \in K_{ijm}} p_{lmik} x_{lmik}} \quad (6)$$

$$w_{jmik} = \frac{\frac{s_{jmik} - s_{lmik}}{\ln s_{jmik} - \ln s_{lmik}}}{\sum_{i \in K_{jmi}} \frac{s_{jmik} - s_{lmik}}{\ln s_{jmik} - \ln s_{lmik}}} \quad (7)$$

At the individual product level, it holds that the intensive margin is equal to

$$IM_{jmi} = P_{jmi} X_{jmi} \quad (8)$$

X_{jmi} is the quantity index corresponding to the price index.

This decomposition methodology is easily computable. In the next section we will compute the extensive margin, the intensive margin and the quality and quantity components for each European Union exporter in each European Union member state market for several sectors. We focus on the sectors within the manufacturing sector. In section 4 we then regress these indicators on a number of country and sector characteristics (see below). This entire analysis is similar to Hummels and Klenow's work. However, there are two important differences in our approach. First, we use

only intra-European Union trade flows in order to reduce the impact of trade policies and other hampering barriers to trade on the results. Trade policies and barriers to trade affect in particular the price of exported goods, hence our study reduces such possible bias⁷. Secondly, we calculate the indicators at the sectoral level instead of at the country level. This allows us to take into account sectoral characteristics. In particular we will focus on the role of technological indicators in the variety and quality pattern of intra-European trade.

3. EVIDENCE REGARDING VARIETY AND QUALITY OF INTRA-EUROPEAN MANUFACTURING TRADE

In order to compute the different components reflecting the importance of variety and quality of intra-European Union trade, we take trade data from UNCTAD (2008). We use the most detailed data available, i.e. export flows at the 6-digit level of the Harmonised System (version 2002). According to this classification total trade flows are divided into 5017 product categories. In order to compute the extensive and intensive margins, and the quantity and quality components of the latter, we aggregate these data at the sectoral level (22 manufacturing sectors). We aggregate at the 2-digit ISIC revision 3 classification. Hence each product is assigned to a particular ISIC revision 3 sector, according to a conversion table between the two classifications⁸. At the 2-digit ISIC revision 3 level we can study the impact of sectoral characteristics on the sectoral indicators of variety and quality, which is impossible at more detailed levels since no such data for possible determinants are available.

In this section we briefly summarize some of the characteristics of the variety and quality pattern of intra-European exports. The large amount of data and dimensions in the data make it hard to summarize the measurement of the extensive and intensive margin, and the quality and quantity components within the scope of this paper⁹. Generally speaking, we find considerable heterogeneity, in the sectoral as well as in

⁷ See Debaere and Mostashari (2007) for a study about the impact of tariffs on the extensive margin in US trade. They show that tariff reductions lead to trade in new goods.

⁸ Available from the RAMON Eurostat Metadata Server.

⁹ All more detailed data are available upon request.

the cross-country dimension. However, in comparison with the findings by Hummels and Klenow (2005), there appear to be larger differences in the relative importance of variety and quality in intra-European trade than in trade in general.

In order to give the reader at least some idea about the patterns of variety and quality in intra-European trade, Table I provides some summary statistics for each European exporter. The table gives the average value of the extensive and intensive margins as well as of the price and quantity components, measured across all sectors and destination markets. Also the variance and skewness of the data are provided to give some idea about the distribution of the data. Similar summaries can be discussed for all European importers, or for each industrial sector. However that is beyond the scope of this paper.

Some observations are possible. First, for all components the differences across European countries are relatively large, with some clear outliers (e.g., high price components for The Netherlands and Sweden). Secondly, the variance within each exporter, hence across sectors and destination markets, also varies a lot across exporters. These first two observations point to large levels of heterogeneity in the pattern of variety and quality in intra-European trade. Thirdly, we observe that the extensive margin is larger than the intensive margin for all European exporters. Hence the European countries export on average more varieties rather than a large value of each product. Finally, for all countries, the price component exceeds the quantity component. The latter two conclusions were also obtained by Hummels and Klenow (2005 - Table A1), although their average values (based on total trade and more destination countries) are usually lower. Regardless of these clear findings, it is hard to interpret them. Therefore we proceed to an analysis of the determinants of this heterogeneity in the next section.

TABLE I: Summary Statistics for the Variety and Quality Pattern across European Exporters

		Extensive Margin	Intensive Margin	Price Component	Quantity Component
Belgium	average	0.89	0.11	2.02	0.10
	variance	0.04	0.01	56.93	0.01
	skewness	-2.62	1.46	11.12	1.59
Denmark	average	0.75	0.04	1.41	0.03
	variance	0.05	0.00	0.48	0.00
	skewness	-1.19	2.69	4.03	2.72
Germany	average	0.95	0.26	1.01	0.26
	variance	0.01	0.02	0.05	0.02
	skewness	-4.64	1.06	0.50	1.22
Finland	average	0.63	0.03	1.61	0.03
	variance	0.07	0.00	1.85	0.00
	skewness	-0.50	2.87	3.82	3.24
France	average	0.94	0.15	1.11	0.15
	variance	0.02	0.01	0.08	0.01
	skewness	-3.87	2.04	1.47	1.90
Ireland	average	0.47	0.04	1.82	0.03
	variance	0.09	0.00	5.21	0.00
	skewness	0.21	3.94	7.85	3.35
Italy	average	0.90	0.12	1.05	0.13
	variance	0.03	0.01	0.13	0.01
	skewness	-2.83	1.68	2.26	2.03
The Netherlands	average	0.85	0.06	5.36	0.05
	variance	0.04	0.00	1.08	0.00
	skewness	-2.30	2.53	9.76	3.25
Spain	average	0.83	0.05	1.19	0.05
	variance	0.04	0.00	1.31	0.00
	skewness	-2.00	2.78	8.76	2.93
United Kingdom	average	0.89	0.18	1.21	0.16
	variance	0.04	0.03	0.23	0.03
	skewness	-2.63	2.06	7.99	2.11
Sweden	average	0.79	0.07	8.21	0.06
	variance	0.05	0.01	2.46	0.01
	skewness	-1.20	2.46	7.52	2.77

Notes: The average is calculated as the arithmetic average of each component's values across sectors and destination markets for each exporting country.

4. EMPIRICAL MODEL AND ESTIMATION METHODOLOGY

4.1 Trade and quality: a difficult relationship

The Feenstra-Hummels-Klenow decomposition methodology is useful for getting a better insight into the relative importance of variety and quality in international trade. However the evidence regarding quality may be criticized, since it makes the strong

presumption that unit values are a correct reflection of quality. Although often used in empirical trade research (see e.g., splitting up intra-industry trade into horizontal and vertical intra-industry trade), unit values are at best a proxy for price differences for several reasons¹⁰.

First, domestic goods' prices may differ from traded goods' prices because of strategic export policy, trade restrictions, market segmentation strategies etc. Secondly, even if unit values are closely related to real prices, other things apart from quality may affect prices, e.g. market competition (for recent work see Amiti and Khandelwal (2009)). Nevertheless the analysis based on unit values remains useful. But we have to look, in addition to the mere computation of the different components, at the effect of income on the quality component of bilateral trade flows. That is what we do in this section. Since, however, the income elasticity of each component can only be correctly estimated if one takes into account other determinants as well (in order to avoid an omitted variable bias), we perform a full analysis regarding the determinants of variety and quality of trade.

4.2 Empirical model and estimation methodology

For each sector and for each exporter in each import market we construct the extensive margin, the intensive margin, and the quantity and quality components of the intensive margin. Each of these margins or components (generally denoted by Q_{jmi}) are regressed on a number of country and sectoral characteristics. We estimate the following model (all variables in natural logs):

$$Q_{jmi} = \alpha + \alpha_i + \beta_1 GDP_j + \beta_2 GDP_m + \beta_3 \left(\frac{GDP_j}{POP_j} \right) + \beta_4 \left(\frac{GDP_m}{POP_m} \right) + \beta_5 TECH_{j(m)i} + \beta_6 SPIL_{ji} + \beta_7 DIST_{jm} + \varepsilon_{jmi} \quad (9)$$

As to country-level characteristics, we take into account, following the earlier evidence, the role of country size (GDP) and income (GDP per capita, GDP divided

¹⁰ See also Gaulier et Méjean (2006).

by total population, denoted by POP) of both the importer and exporter country. At the sectoral level, we try to answer two questions. First, we wonder whether the technological performance of the exporter country has a statistically significant impact on the variety and/or quality of its sectoral bilateral trade. Secondly, we investigate whether additionally international technological spillovers matter for variety and quality of trade. We control for unobserved fixed effects at the sectoral level. Since these data are clustered in both the exporter and importer dimension, we estimate this model by a GEE estimator.

Consecutively we use four different measures for technological innovativeness (all denoted in the empirical specification by $TECH_{j(m)i}$). First, we use a bilateral technological performance indicator, defined as

$$BILTECH_{jmi} = \frac{\frac{T_i^j}{\sum_{i'=1}^I T_{i'}^j}}{\frac{T_i^m}{\sum_{i'=1}^I T_{i'}^m}} \quad (10)$$

This indicator measures the technological performance of a particular sector i in a particular exporting country j , relative to both the overall technological performance of country j , and the sectoral and overall technological performance of the trading partner m . We separately use the patent stocks and R&D expenditures in this calculation.

Secondly, we also calculate the multilateral counterpart of this indicator, namely MULTITECH, again based on either patent stocks or R&D expenditures:

$$MULTITECH_i^j = \frac{\frac{T_i^j}{\sum_{j'=1}^J T_i^{j'}}}{\frac{\sum_{i'=1}^I T_{i'}^j}{\sum_{i'=1}^I \sum_{j'=1}^J T_{i'}^{j'}}} \quad (11)$$

For the multilateral indicators we use the European Union level (defined as the 11 countries included) as "the world". These technological indicators reflect different measurement techniques of technological performance as applied throughout the literature. Patents are an output innovation indicator, reflecting successful innovation efforts at the sectoral level. On the other hand, innovation efforts are not always successful, and hence do not always lead to patent grants. Therefore we choose an alternative measure of technological innovation using R&D expenditures (the so-called input innovation indicator). Logically, the bilateral indicators vary in the three dimensions of our data, but the multilateral indicators differ only across exporters and across sectors.

Apart from indicators of technological performance, we also take into account indicators of international technological spillovers:

$$SPIL_{ji} = \ln \left(\sum_{d \neq j}^J \theta_{dj} S_d \right) \quad (12)$$

where S_d is the R&D capital stock of foreign country d , and where θ_{dj} is the share of country j 's bilateral machinery and equipment imports from foreign country d in country j 's total machinery and equipment imports (averaged over time). There is considerable evidence that such spillovers take place, in particular between open economies (see e.g., Keller (2004)). Although many approaches are possible, we focus on intra-European intra-sectoral technology spillovers in this paper. Such spillovers may have an impact on diverse economic phenomena. We distinguish between two indicators, inspired by the two main channels through which spillovers take place, i.e. imports and foreign direct investment (FDI). Hence we take the sum of

the total number of patents granted to each EU-country in the U.S. in sector i weighted by, on the one hand, the total import share of each country in total EU imports by country j and, on the other hand, the stock of FDI share of each country in total stock of EU FDI in country j . Since the results for FDI spillovers appear to be insignificant overall, we don't report the findings for the FDI-based spillovers, but focus on import-based spillovers only in the discussion of the results.

The patent data come from the United States Patent and Trademark Office (USPTO). Patent data from the (large) U.S. market can be considered as a proxy for technological performance in the entire world. Data are converted from ussic to ISIC revision 3. R&D expenditures and value added are taken from the OECD (2008b) STAN database and the OECD (2008a) Science, Technology and Industry Outlook. Distance (in km) is from www.mappy.com. GDP and population data come from IMF (2008) Outlook Database. Foreign direct investment data are taken from the UNCTAD (2008). Due to data limitations related to the innovation indicators we focus on a single year, 2002, i.e. the most recent and complete data available.

5. DETERMINANTS OF VARIETY AND QUALITY OF INTRA-EUROPEAN MANUFACTURING TRADE

Given the substantial heterogeneity in the variety and quality patterns for intra-European trade, we concentrate in this section on the determinants of the observed variety and quality patterns. The estimation results for the extensive margin and the intensive margin can be found respectively in Table II and Table III. Table IV and Table V show the results for respectively the price component (hence quality) and quantity component of the intensive margin. We estimate the same model for each of these dependent variables. In our discussion we focus on the impact of each independent variable on each of the dependent variables, rather than discussing table by table.

TABLE II: Regression Results for the Determinants of the Extensive Margin in Intra-EU Manufacturing Trade

Dependent Variable: Extensive Margin	(1)	(2)	(3)	(4)	(5)
exporter's income	0.17 *	0.16 *	0.08 *	0.16 *	0.13 *
	0.01	0.02	0.02	0.02	0.01
importer's income	0.08 *	0.07 *	0.06 *	0.06 *	0.06 *
	0.01	0.02	0.02	0.02	0.02
exporter's income per capita	-0.49 *	0.02	-0.39 *	-0.14	-0.13
	0.08	0.14	0.11	0.18	0.19
importer's income per capita	-0.08	-0.13	-0.13	-0.25 *	0.19
	0.07	0.08	0.11	0.12	0.01
distance	-0.19 *	-0.15 *	-0.20 *	-0.21 *	-0.21 *
	0.02	0.02	0.02	0.03	0.03
technological innovation - patents		0.06 *		0.09 *	0.07 *
		0.01		0.03	0.19
technological innovation - R&D			0.00	-0.03	-0.03
			0.01	0.03	0.03
technological spillovers - trade					0.00
					0.03
constant	5.31 *	0.60	5.60 *	4.02	3.41
	1.29	1.96	1.93	2.57	1.88
F.E.	yes	yes	yes	yes	yes
R ² within	0.19	0.17	0.14	0.20	0.23
F	75.75	28.94	25.27	15.52	15.52

*Notes: Estimation results based GEE estimation with fixed effects; robust estimation with clustering on sector-country dimension; standard errors in parentheses; * significant at 10 %; all variables except the dependent variable are measured in natural logs.*

Our findings for intra-European export flows are in line with previous studies. We confirm the important role of income per capita and country size in general. We start by discussing the size and income effects. As to size, the extensive margin is positively affected by both exporter's and importer's size (income), overall across all sectors. Hence larger countries trade more at the extensive margin than smaller countries, i.e. larger countries export and import more varieties which causes higher total trade flows. The impact of the exporter's size clearly exceeds the effect of importer's size (more than double). Moreover, from Table II we learn that the intensive margin is also positively affected by the size of exporting countries. Exporter income elasticity is very high (about 0.70-0.80). It appears that larger economies export more both at the extensive and intensive margin, but they import more only at the extensive margin. So although they both sell a higher number of varieties and at a higher value (either resulting from higher quantities or higher prices) than other EU-countries, they spend more on foreign varieties whilst not buying more different varieties. Finally, from the decomposition into price and quantity components it becomes clear that larger countries export more of the same varieties

but at a lower price. Hence they benefit from a volume effect, possibly created by production scale effects that offer them a price advantage.

TABLE III: Regression Results for the Determinants of the Intensive Margin in Intra-EU Manufacturing Trade

Dependent Variable: Intensive Margin	(1)	(2)	(3)	(4)	(5)
exporter's income	0.80 *	0.81 *	0.72 *	0.83 *	0.79 *
	0.03	0.04	0.03	0.05	0.05
importer's income	-0.03	-0.05	0.03	0.00	0.00
	0.03	0.04	0.04	0.06	0.06
exporter's income per capita	0.01	0.33	0.57 *	0.31	0.30
	0.16	0.31	0.20	0.37	0.38
importer's income per capita	-0.39 *	-0.38	-0.49 *	-0.69 *	-0.71 *
	0.17	0.23	0.26	0.32	0.32
distance	-0.67 *	-0.64 *	-0.64 *	-0.69 *	-0.74 *
	0.03	0.05	0.05	0.06	0.06
technological innovation - patents		0.06 *		0.06	0.05
		0.02		0.04	0.08
technological innovation - R&D			0.14 *	0.14 *	0.14 *
			0.03	0.06	0.07
technological spillovers - trade					0.08 *
					0.01
constant	0.71 *	-2.38	-3.45	1.37	2.34
	2.83	4.63	4.00	6.17	4.39
F.E.	yes	yes	yes	yes	yes
R ² within	0.40	0.40	0.36	0.43	0.47
F	296.30	119.09	100.84	60.15	89.33

*Notes: Estimation results based GEE estimation with fixed effects; robust estimation with clustering on sector-country dimension; standard errors in parentheses; * significant at 10 %; all variables except the dependent variable are measured in natural logs.*

We now turn to the evidence about countries' income. Controlling for country size, there is clear evidence that richer countries' exports are less diversified. Hence the importance of variety is much more driven by countries' size than by countries' income. A possible explanation is that richer countries are more selective in the products that they sell. Although the exporter's income doesn't significantly affect the intensive margin, the decomposition into quantity and price is very instructive. We find that richer countries sell products at higher prices, which is equivalent to higher quality exports. However they don't sell these high quality goods in large quantities. Surprisingly, richer countries do not seem to import higher quality products. Actually both the importer's size and income have hardly any effect on the observed pattern of trade. These findings are of course only based on the overall income elasticity that we show here, regardless of the sectors. The income elasticities are likely to differ across sectors (and even within these sectors). We leave this issue for future research.

As to the effect of distance we can be very clear. It has a clearly negative effect, both on the extensive and intensive margin, hence both on the number and on the value of varieties traded. Separating the effect on prices and quantities, the results show that a larger distance between trading partners lowers the trade volume (equivalent to the trade reducing effect of larger trading and transportation costs). However, the effect on prices is positive, although rather small. Hence more distant trading partners trade higher quality goods. This latter finding is a confirmation of the Alchian-Allan conjecture in intra-EU trade.

TABLE IV: Regression Results for the Price Component in Intra-EU Manufacturing Trade

Dependent Variable: Price Component	(1)	(2)	(3)	(4)	(5)
exporter's income	-0.10 *	-0.09 *	-0.04 *	-0.14 *	-0.09 *
	0.01	0.02	0.02	0.04	0.04
importer's income	0.00	-0.02	-0.02	-0.05	-0.01
	0.02	0.03	0.03	0.05	0.05
exporter's income per capita	0.50 *	0.22 *	0.49 *	-0.02	0.67
	0.07	0.13	0.11	0.17	0.13
importer's income per capita	-0.03	-0.12	-0.18	-0.39	-0.31
	0.11	0.17	0.17	0.31	0.22
distance	0.08 *	0.03	0.02	-0.08	0.03
	0.02	0.04	0.04	0.07	0.06
technological innovation - patents		-0.01		-0.20 *	-0.20 *
		0.02		0.07	0.04
technological innovation - R&D			0.03 *	0.09 *	0.10 *
			0.01	0.03	0.01
technological spillovers - trade					0.04 *
					0.00
constant	-4.54 *	-0.42	-2.62	5.90	3.45
	1.66	2.54	2.48	4.41	4.66
F.E.	yes	yes	yes	yes	yes
R ² within	0.05	0.02	0.03	0.05	0.12
F	41.17	9.94	13.65	3.37	15.78

*Notes: Estimation results based GEE estimation with fixed effects; robust estimation with clustering on sector-country dimension; standard errors in parentheses; * significant at 10 %; all variables except the dependent variable are measured in natural logs.*

TABLE V: Regression Results for the Determinants of the Quantity Component in Intra-EU Manufacturing Trade

Dependent Variable: Quantity Component	(1)	(2)	(3)	(4)	(5)
exporter's income	0.89 *	0.90 *	0.76 *	0.98 *	0.75 *
	0.03	0.04	0.04	0.07	0.07
importer's income	-0.03	-0.04	0.06	0.05	0.03
	0.03	0.05	0.05	0.08	0.09
exporter's income per capita	-0.49 *	0.11	0.07	0.33	0.45
	0.18	0.35	0.23	0.42	0.44
importer's income per capita	-0.33 *	-0.26	-0.34	-0.30	-0.40
	0.20	0.28	0.31	0.44	0.43
distance	-0.75 *	-0.67 *	-0.66 *	-0.61 *	-0.67 *
	0.04	0.06	0.07	0.10	0.14
technological innovation - patents		0.08 *		0.26 *	0.14 *
		0.03		0.09	0.07
technological innovation - R&D			0.10 *	0.05	0.07
			0.03	0.06	0.31
technological spillovers - trade					0.03 *
					0.01
constant	5.06	-1.96	-0.52	-4.53	-2.18
	3.27	5.50	4.84	7.98	8.55
F.E.					
R ² within	0.39	0.36	0.29	0.31	0.34
F	321.00	120.34	91.04	53.42	67.74

*Notes: Estimation results based GEE estimation with fixed effects; robust estimation with clustering on sector-country dimension; standard errors in parentheses; * significant at 10 %; all variables except the dependent variable are measured in natural logs.*

Finally we discuss the effect of technological innovation and technological spillovers¹¹ on the variety and quality of intra-EU trade. The findings for the extensive margin are mixed. If countries are, in a particular sector, technologically superior compared to their bilateral trading partner in terms of patents, then their sectoral export is less diversified. However if they spend more on R&D relative to the entire EU, they will export more varieties in this sector. Hence the impact of technological innovation on the extensive margin depends on the technological indicator used. Technological spillovers, however, have a positive and relatively large impact on variety in European sectoral trade. The intensive margin is negatively affected by both patents and R&D expenditures. Moreover technological spillovers do not play a role in the intensity of traded goods. However if one decomposes the intensive margin once more, it becomes clear that this total negative effect is the result of a negative impact on the quantity component. The quality/ price component, on the other hand, is

¹¹ We only report the results for the international technological spillovers through the trade channel since the alternative results based on the FDI channel are always insignificant.

positively affected by innovation, although the coefficients are not always significantly different from zero. This implies that there is some evidence that innovative sectors are able to produce higher quality goods that are sold at higher prices, but at lower volumes. Also technological spillovers positively affect the quality of European traded goods, but not the quantity. So domestic sectors are able to improve their quality thanks to foreign knowledge spillovers through trade contacts, but these spillovers do not raise the volume sold. Finally note that, although not reported, these findings are robust to the joint inclusion of both domestic technological innovation and international technological spillovers within the model specification.

6. CONCLUSION

We calculated the importance of variety and quality in intra-European trade. There appears to be a considerable level of heterogeneity in sectoral and cross-country importance of variety and quality. We tried to explain this variation by looking into the role of technological innovation and international technological spillovers apart from the well-documented role played by income and country size. Moreover we take into account the role of geographical distance.

Country characteristics are important to explain the pattern of variety and quality in intra-EU trade flows. Larger EU-countries sell both a higher number of varieties and varieties of higher value than smaller EU countries, but they sell them at a lower price. Larger countries also buy more different varieties, but this doesn't mean that the value of what they import is greater than that of other countries. Richer countries, which are mostly relatively capital intensive, export higher quality products across sectors. The richer the exporting countries are, the smaller the number of varieties exported. Larger countries import more different varieties in the EU, but there is hardly any evidence for a role played by importer country characteristics. Consequently there is no evidence found in favour of the Linder hypothesis in the EU. The evidence for the distance between countries, reflected mostly in transportation costs in the context of the integrated European market, points to an interesting story: distance reduces the number of varieties traded within sectors as well as the total

value of traded varieties, but it increases the average quality of the varieties that are traded.

Hence we are able to show at least some detailed patterns underlying typical gravity findings. Consumers are more likely to be willing to pay for transportation costs, if the imported goods are characterized by a better quality. The sectoral innovation performance of the domestic economy relative to its bilateral trading partner or to the EU as a whole plays a somewhat ambiguous role. R&D expenditures tend to increase the variety in intra-EU trade, but patents reduce it. It seems as if efforts to develop new products increases the product variety, but once successful new products are protected by a patent, firms no longer have an incentive to come up with new differentiated products. Innovation also negatively affects the intensity of traded goods. However the results point to a quality-upgrading effect since lower volumes are exported at higher prices, reflecting higher quality. Finally, we find evidence that technological spillovers increase, first, the variety in intra-EU trade, and secondly, the quality of the traded goods. These findings call for more theoretical underpinnings. None of the existing trade models is able to account for every aspect of these observed trade patterns. Technological innovation and international technological spillovers are important sources for the competitiveness of nations. The exact way in which they affect a country's export performance should be modeled in future research, preferably in a testable theoretical framework¹².

¹² Recent work by Hallak and Schott (2008) and Schott (2008) is very promising.

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