How Geography Affects Quality*

Volodymyr Lugovskyy, Georgia Institute of Technology†
Alexandre Skiba, University of Wyoming‡

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Abstract

This paper investigates how a country's geographic position relative to other countries affects the quality of its exports. The two driving forces are the supply-side response to the specific transportation cost (generalized Alchian-Allen effect) and the stronger preference for quality in richer countries. Producers who may be unable to adjust quality for every market will choose a common quality level that is a function of their destinations' trade-weighted average preference for quality and specific transportation cost. The data confirm the theoretical prediction. Exporters of differentiated goods that face a stronger demand for quality from richer countries charge 5–9% more for all destinations. At the same time, countries whose demand is especially distorted by the Alchian-Allen effect charge 14–24% more. Moreover, geography is more significant to the quality choice of developing countries. Multilateral geographic factors explain 7.6% of the price variation for the non-OECD exporters, and only 4.2% for the OECD exporters. The Alchian-Allen effect influences an exporter's quality roughly two to three times as much as the proximity to rich importers does.

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†School of Economics, Georgia Institute of Technology, Atlanta, GA 30332-0615; e-mail: volodymyr.lugovskyy@econ.gatech.edu

‡Corresponding author. Department of Economics and Finance, University of Wyoming, Dept 3985, 1000 E University Ave, Laramie, WY 82071, e-mail: askiba@uwyo.edu

1 Introduction

A growing number of recent empirical literature have documented the importance of quality in international trade, and multiple factors have been shown to affect the quality of traded goods, such as income per capita of the importer and exporter (Linder conjecture),[1] factor endowments,[2] formal trade barriers,[3] transportation costs (Alchian-Allen effect),[4] the import of intermediate goods, and R&D expenditures. The literature suggests that while it is mostly ignored by major traditional trade theories, vertical differentiation is an important source of comparative advantage and a significant determinant of trade.

This paper studies how geography affects specialization in vertically differentiated products. Understanding the role of geography in determining the quality of exports is crucial because product quality can mitigate the detrimental effect of remoteness that is created by geographic frictions. First, higher quality products are less susceptible to geographic frictions. Geography can affect trade negatively, as distance acts as an impediment to trading activity. Thus, upgrading quality compensates for such geographic trade barriers by reducing the effect of trade cost on the delivered price. For example, the specific shipping cost affects the delivered price of an expensive Mercedes to a smaller degree than that of a cheaper Hyundai. Drawing a parallel to the Alchian-Allen effect, the good apples are relatively cheaper to ship than the bad apples.

Second, a producer can reduce this geographic disadvantage by choosing the quality that best suits most of its consumers worldwide.[5] Since income is a major quality demand shifter, the income level of both domestic and foreign consumers influences the producer's quality choice. This effect is similar to the Linder conjecture. For example, the lower quality, cheaper vehicles produced by Indian car manufacturer Tata and Chinese car manufacturer Geely are a better match quality-wise to the demand of the large number of nearby customers than the more expensive brands. Therefore, note that if major foreign markets are populated by lower income consumers, this effect might contradict the original Alchian-Allen effect that is partially predicated on the similarity in demand for quality across states. If the apple exporting state of Washington had a much higher demand for quality than the importing state of New York, the Linder conjecture could possibly counteract the Alchian-Allen effect, e.g., Washington could ship bad apples to New York. To understand the interaction between

[1] Linder (1961) was the first to point out the stronger demand for higher quality in richer countries and the consequent demand driven comparative advantage of richer countries in higher quality. Among others, Hallak (2006), Bastos and Silva (2009), and Manova and Zhang (2009) confirm that higher unit value goods are exported to richer countries, while imports from richer countries are of a higher unit value as well.

[2] In particular, see the pioneering work of Schott (2004).

[3] Amiti and Khandelwal (2009) show that lower tariffs encourage (discourage) quality upgrading for products close to (far from) the world frontier.

[4] Hummels and Skiba (2004) document Alchian-Allen effect in international trade.

[5] "Quality, quality, and quality" was a response of an executive of a leading Mexican juice producer when asked what it takes for a company like his to become an exporter (Iacovone and Javorcik (2010)).

the two effects, consider a Washington farmer choosing what quality apples to grow, given that the apples will be sold both in Washington and New York. The farmer's quality choice depends on on the level of income in each state, the relative importance of each market, and the transportation cost between Washington and New York. In more general terms, the relative geographic position of a country alters the benefits to quality upgrading, and a firm chooses a quality that is generally different from the optimal autarky levels.

Surprisingly, there is no research on how quality specialization is affected by the geographic position of a country-exporter. The existing literature models the quality of a country's export as a function of exporter's, importer's, or importer-exporter's characteristics (e.g., incomes per capita or bilateral tariffs and transportation costs). The question of whether and how the demands from *all* international locations affect the quality choice of firms-exporters has yet to be explored.[6] To the best of our knowledge, our paper constitutes the first attempt to fill this gap. We show how a country's geographic position can influence a firm's quality choice. Based on our model, we quantify this determinant into the Multilateral Quality Compensation (MQC) term, which incorporates the information on the proximity, income, and relative size of export destinations. Empirically, we show that MQC explains 7.6% of the price variation for the non-OECD exporters and 4.2% for the OECD exporters. To compare, the GDP per capita, which is the most widely used explanatory factor of quality, explains 15.8% of the price variation for the non-OECD exporters and 9.0% for the OECD exporters.

Our model generalizes the Linder assumption and the Alchian-Allen effect to a multilateral setting. In a multi-country model with arbitrary distributions of country-specific preferences for quality and of transportation costs, which can be ad-valorem or specific, we examine how the geographic position of a country affects the quality choice of its firms. The answer crucially depends on the flexibility of the technology in terms of tailoring the quality specifically to each destination. Every variety is produced by a mixture of firms each using one of two polar technologies. Some firms have a zero fixed cost of producing destination-specific quality, while others have a prohibitively high fixed cost of producing more than one quality per product variety.

In equilibrium, the 'zero-cost' firms tailor the quality for each export destination.[7] Furthermore, each quality level of the same variety depends on the bilateral transportation cost and the importer's preference for quality. Producers compensate for higher transportation costs by choosing a higher quality, thereby lowering the share of the transportation cost in the delivered price. Similarly, if the consumers in the destination market prefer higher quality than domestic consumers, the firm can

[6] This is unanticipated, given the extensive literature on economic geography and agglomeration highlighting the role of multilateral distance and relative country size on the production locations and patterns of specialization (see, e.g., Fujita, Krugman, and Venables (1999) and Hanson (2005) for an extensive reviews).

[7] A convincing case of the destination-specific quality tailoring in the production of computer printers is presented by Moralez and Sheu (2010).

compensate for the difference in preferences by producing a higher quality variety. The 'prohibitive-cost' firms, on the other hand, choose one-for-all (destinations) quality.[8] The firms choose quality based on the *multilateral* importers preferences and transportation costs. In equilibrium, differentiated varieties of every product are produced by both destination specific and one-for-all quality firm types. As a result, the average quality shipped to any location depends on both bilateral and multilateral factors, where the latter are a function of the exporter's geographic position. Empirically, we capture this idea by constructing an MQC index that combines the trade weighted importers preferences and the composition of transportation costs.[9]

We assume that a higher quality is produced at a higher marginal cost; thus, the higher quality is identified by the higher factory-gate price. Ideally, we need product-firm-importer-exporter data to distinguish between the effects of bilateral and multilateral factors on quality choice. Unfortunately, most of the available trade data, including ours, report goods as Harmonized System (HS) codes that aggregate the output of potentially many firms into broader statistical categories. To match our theory with the level of aggregation in the observed data, we derive an expression for the average price of exports to a given destination that aggregates the price information of both single-quality and multiple-quality varieties. The average price of each product is then decomposed into the exporter and exporter-importer specific components to show how the f.o.b.[10] export price of a given HS product category to a given destination is determined by the importer's preference for quality and bilateral transportation cost as well as by the combined preference for quality from and transportation cost to all destinations.

Based on this decomposition, we estimate the effect of the MQC index on the exporter's base quality level, explicitly accounting for the destination specific quality tailoring. In the empirical exercise, we use data on imports (at 6-digit HS product classification level) into a sample of Latin American countries from all exporters worldwide between 1999 and 2004 to relate the price of exports to the multilateral and bilateral factors. The results confirm the role of geography in explaining the exporter's quality level for differentiated goods. The effect of MQC is significant and robust, and it confirms that the multilateral demand for quality from all destinations plays a significant role in

[8]Intuitively, one can motivate the existence of single-quality varieties either on the basis of technological constraints or reputational effects; for some products (e.g., cars, designer clothing), lowering quality for some destinations might hurt the manufacturer's reputation in global markets. Iacovone and Javorcik (2010) employ Mexican industrial manufacturing firm level data to show that exported varieties are also sold at a higher domestic price. This coincides with the intuition of the single-quality varieties. Exporting to the US increases the average income of a firm's consumers and the average specific transportation cost. According to our model, for single-quality firms, both factors increase the price of products shipped to all destinations. If these firms were able to costlessly tailor the quality for each destination, the price of the products sold in Mexico should not be affected by exporting to the US.

[9]In the gravity and border effect literature, the importance of multilateral factors has been highlighted by Anderson and Van Wincoop (2003) who introduced the "multilateral resistance" term to measure the average trade barrier faced by a given exporter.

[10]"Free on board" price denotes the price of the product placed alongside the ship; it is used as a proxy for the factory price.

the exporters' quality choice. We also find that the the share of export price variation explained by multilateral geographic factors is twice as large for developing countries than it is for developed countries.

While our major focus is on the effect of multilateral geographic factors on the exporter's quality and price levels, a substantial part of the export price variation is explained with the bilateral factors, such as distance and specific and ad-valorem components of transportation costs. Using the unique details of our data, we perform a novel decomposition of the transportation cost into ad-valorem and specific components, where the first component is measured by the transportation insurance cost, and the latter by the remaining part of the transportation cost. Consistent with the theoretical predictions, we find that export prices (i) increase in the specific transportation cost component (Alchian-Allen effect) and (ii) decrease in the ad-valorem transportation cost component (augmented Alchian-Allen effect).[11] These results are consistent with the findings of Hummels and Skiba (2004), who show that export prices increase in specific transportation costs and decrease in duties paid. Another novel result of our paper is that after accounting for the transportation cost, the effect of distance on export prices is statistically insignificant for the OECD exporters and negative for the non-OECD exporters (it is negative in the pooled sample as well).

This paper adds to and relates several literatures central to the understanding of international trade. First, we combine the Linder (1961) assumption that richer countries have a stronger demand for higher quality with the Market Potential Index (MPI) literature. The foundations of the MPI literature can be traced back to the seminal work of Harris (1954), who emphasizes that the demand for goods produced in a given location is the sum of the demands in other locations, which are functions of the purchasing power in those locations, weighted by transportation costs.[12] The MPI is widely used in the economic geography literature (see, e.g., Davis and Weinstein (1999, 2003); Hanson and Xiang (2004); Hanson (2005); Head and Ries (2004)), to capture the idea that a producer's decisions depend on the location and size of its customers and suppliers. We use this idea to show that producers choose their quality on the basis of the preference for quality in *all* of the locations to which they ship, rather than solely on the preferences of their own market.

Second, we contribute to the literature on the Alchian-Allen conjecture by examining how the multilateral and bilateral transportation costs affect quality choice. While the Alchian-Allen conjecture is about the demand-side response to a specific transportation cost, this paper complements the analysis by modeling the supply-side response. In a simple general equilibrium model of trade with endogenous quality choice, we show that a specific transportation cost provides incentives to produce higher quality goods, even though higher quality is more costly to produce, and thus,

[11] As shown theoretically and confirmed empirically by Hummels and Skiba (2004), in the presence of specific trade barriers, ad-valorem trade barriers decrease the average export price.

[12] While until recently, the market potential function was ad-hoc, Fujita, Krugman, and Venables (1999) provided micro foundations for the MPI by showing how it can be derived from formal spatial models.

higher priced. This is due to the delivered relative price of the higher priced goods being lower than the domestic ones. As was first pointed out by Alchian and Allen (1964), specific transportation cost makes producers "ship the good apples out." We show that given a choice, it also creates an incentive to "grow better apples" in order to compensate for the impact of the transportation cost on the delivered price; moreover, we show that the quality shipped to a given country increases in both bilateral and multilateral specific components of the transportation cost.

Third, we contribute to modeling the functional form of the variable transportation cost. Most of the results in the 'new trade' literature are driven by the existence of transportation costs. It is typically expressed in ad-valorem terms as a Samuelson iceberg. Traditionally, this choice is justified on the grounds of analytical simplicity and limited empirical evidence on the functional form of transportation costs. Recent empirical literature, however, clearly shows that the transportation cost is not ad-valorem, and further, that a significant component of the transportation cost is specific.[13] Additionally, Hummels and Skiba (2004) argue theoretically and show empirically that the iceberg assumption is not innocuous; the specific component changes the relative prices of traded goods and shifts the relative demand in favor of higher quality goods, consistent with the Alchian-Allen conjecture. Consequently, the relative demands across importers are not symmetric; in other words, different importers choose different relative quantities from a given exporter. In this paper, we also deviate from the standard Samuelson iceberg functional form in allowing for the transportation cost to consist of both ad-valorem and specific components. However, contrary to Hummels and Skiba (2004), we assume that even though a part of the transportation cost is specific, the transporters charge for the service in units of the delivered product. The transporters post a schedule of the ad-valorem transportation cost for each quality level. As a result, the transportation cost preserves the convenient feature of the traditional ad-valorem iceberg. However, at the same time, higher quality goods face smaller transportation costs in ad-valorem terms.

Our results can be useful to several other important strands of literature on quality and trade. The discussion on the correlation between quality and productivity in the heterogeneous firms framework was recently initiated by Baldwin and Harrigan (2007). In Melitz (2003), quality differentiation is assumed away, and the lowest (marginal) cost firms are the most productive. Baldwin and Harrigan (2007) challenge this assumption and propose a variant of Melitz's model in which higher cost firms are higher quality and also higher productivity firms. Empirically, the claim is supported by showing that the factory prices of exported goods increase with the distance to the destination. Following Hummels and Skiba (2004), we show that the positive correlation between the distance to the destination and export prices can stem not only from the self-selection of higher quality firms to more remote locations but also from the supply-side Alchian-Allen effect, even if

[13]See, e.g., Hummels and Skiba (2004), Hummels, Lugovskyy, and Skiba (2009), and Irrarazabal, Moxnes, and Opromolla (2010).

the set of exporting firms is constant for all locations. We also show that after we account for the transportation cost, the effect of distance on bilateral factory-price is negative.

Our model abstracts from the firm heterogeneity model because our focus is on the relative demands and not on the sorting of firms into exporters and non-exporters. The main theoretical mechanism in the models with heterogeneous firms is that the cost of exporting reduces the set of exporters. Depending on the relation between the profits and price, the exporters can be either low or high cost producers. The nature of transportation costs and the differences in relative demands for quality do not play a role. A notable exception is presented by Irrarazabal, Moxnes, and Opromolla (2010) in their study of the distributional effects of a specific trade cost. They find that the variation in the distribution of firm export values is consistent with a fairly substantial specific trade cost.

Our work is closely related to the within-industry specialization literature. Krugman (1979) and Krugman (1980) describe how specialization can occur within the increasing returns to scale industry or even within a differentiated product. An important implication of his seminal work lies in its formal description of the home market effect that states that specialization due to increasing returns can be detected by the relationship between the quantity of exports and the market size. The more than proportional correlation between exports and size indicates that larger countries specialize in the increasing returns sector. Further pursuing this line of research, Schott (2004) and Hallak (2006) detect substantial within-product specialization and point out that richer countries specialize in higher quality products, particularly highlighting considerable vertical, international specialization, even within the most narrowly defined product categories. We extend this literature by showing that the within-product and within-industry specialization in vertically differentiated products depend on the geographic position of the country-exporter.

Recently, the exporter's quality choice was studied by Verhoogen (2008), who studied quality upgrading among Mexican exporters to the US. This work showed that the quality difference among exporters and non-exporters is driven by the American preference for quality and not the nature of the transportation cost. Our empirical exercise allows for quality preferences by high income countries, but the main focus is on the transportation cost.

Furthermore, Gervais (2010) studied endogenous quality choice by heterogeneous firms, mainly focusing on the relationship between productivity and quality. In his model, the cost of exporting makes only the most productive firms export. Since productive firms can upgrade quality more easily, the exporters produce a higher quality. His results are not contingent on the non-iceberg nature of the transportation costs or incomes per capita of the destination countries. Transportation cost plays a role to the extent that it presents a cost disadvantage that can be overcome by firms with higher productivity. Our study is complementary to this in that it concentrates on the composition of the foreign demand and its effect on quality.

The rest of this paper is organized as follows: we describe the theoretical framework in section 2, present empirical findings in section 3, and conclude in section 4.

2 Theoretical Framework

Consider many monopolistically competitive firms in a given sector $g = 1, 2, ..., G$. Each firm can produce a differentiated variety, in which case it will face demands from $i = 1, 2, ..., I$ countries. Producers have control over the quality level of their output, where a higher quality requires a higher marginal cost. Some firms can easily adjust the quality for each export destination, while others can choose only a single quality for all destinations, since for them, destination-specific quality tailoring is prohibitively expensive. For single-quality firms, the equilibrium quality level is a function of geography, which is the main distinction of our model. In particular, equilibrium quality increases in the weighted average intensity of all export destinations' preference for quality[14] and decreases in the weighted average ad-valoremness[15] of the transportation cost (the weights are the values of the shipments to each country). On the other hand, multiple-quality firms consider only the intensity of the target destination's preference for quality and bilateral ad-valoremness of the transportation cost. For a given sector, the quality and the average price of exports will be a function of both the average and destination-specific parameters.

2.1 Preferences

Preferences are asymmetric across countries. A representative consumer in country i has a Cobb-Douglas utility function across sectors $g = 1, 2, ..., G$ differentiated by the producers location in country $j = 1, 2, ..., I$:

$$U_i = (x_{0i})^{\eta_0} \prod_{g=1}^{G} \prod_{j=1}^{I} \left(\Gamma_{gij}^{1-k_g} \Theta_{gij}^{k_g} \right)^{\eta_{gij}} \qquad \eta_0 + \sum_{j=1}^{I} \sum_{g=1}^{G} \eta_{gij} = 1; \quad 0 < k_g < 1; \tag{1}$$

where x_{0i} is the individual consumption of the numeraire; $\eta_{gij} \geq 0$ is the expenditure share in country i on the differentiated goods of sector g produced in country j, which is split between composite goods Γ_{gij} and Θ_{gij}. Note that some expenditure shares can be zero, allowing for zero-

[14]Following Linder's (1961) assumption, we allow for the intensity of the preference for higher quality to differ across countries.

[15]In addition to production costs, exporters incur transportation costs, where the variable transportation cost consists of the ad-valorem and specific components. The ad-valoremness of the transportation cost measures the share of the ad-valorem component in the total (variable) transportation cost.

trade at the sectoral level for some country pairs. We denote the set of countries with a positive share of expenditure on varieties produced by country j in sector g as Ψ_{gj}:

$$\forall i \in \Psi_{gj} : \eta_{gij} > 0 \tag{2}$$

The good Γ_{gij} (Θ_{gij}) is a composite of many symmetric varieties, where $\sigma > 1$ is the elasticity of substitution between any two:

$$\Gamma_{gij} = \left(\sum_{v \in \gamma(g)} \left(\lambda_{vij}^{\delta_{gi}} x_{vij} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \qquad \Theta_{gij} = \left(\sum_{v \in \theta(g)} \left(\lambda_{vij}^{\delta_{gi}} x_{vij} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

where λ_{vij} is the quality level of differentiated variety v produced in country j for country i; δ_{gi} is the intensity of the preference for quality in country i's sector g;[16] and x_{vij} is the individual consumption of variety v produced in country j.

2.2 Production

Labor is the only factor of production, and it is supplied inelastically. There are L_i consumers in country i, and each is endowed with one unit of labor. The numeraire sector is characterized by perfect competition and constant returns to scale. One unit of labor can produce w_i units of the numeraire in country i, and it is traded at zero cost. We assume that the numeraire sector is large enough for all countries to have a strictly positive output of the numeraire. The introduction of the numeraire in the model simplifies the balance of trade calculation and ties the wage to productivity in the numeraire sector.

Differentiated sectors are characterized by monopolistic competition. The variable cost function of sector g's variety v produced in country j is country and sector specific and is characterized by marginal labor requirement b_{vj}, which is a function of the chosen quality level λ_{vij}. In each sector, we assume that the technology is such that there exist maximum and minimum quality levels, $\underline{\lambda_g}$ and $\overline{\lambda_g}$, respectively. We do not limit a firm's choice to either high or low quality levels; rather, we allow for a continuous quality choice within the following range:

$$b_{vj}\left(\lambda_{vij}\right) = B_{gj} \exp\left(\lambda_{vij}/\beta_{gj}\right) \qquad B_{gj}, \beta_{gj} > 0; \lambda_{vij} \in \left[\underline{\lambda_g}, \overline{\lambda_g}\right] \tag{4}$$

where B_{gj} and β_{gj} are sector and country specific productivity parameters.[17]

[16]We introduce and define the preference for quality to be destination-specific, following the model of Hallak (2006). The intuition is that a good of the same quality is perceived differently across countries, and upgrading quality increases the marginal utility at different rates across countries.

[17]A similar marginal cost function was first introduced by Flam and Helpman (1987) and later used by Hummels

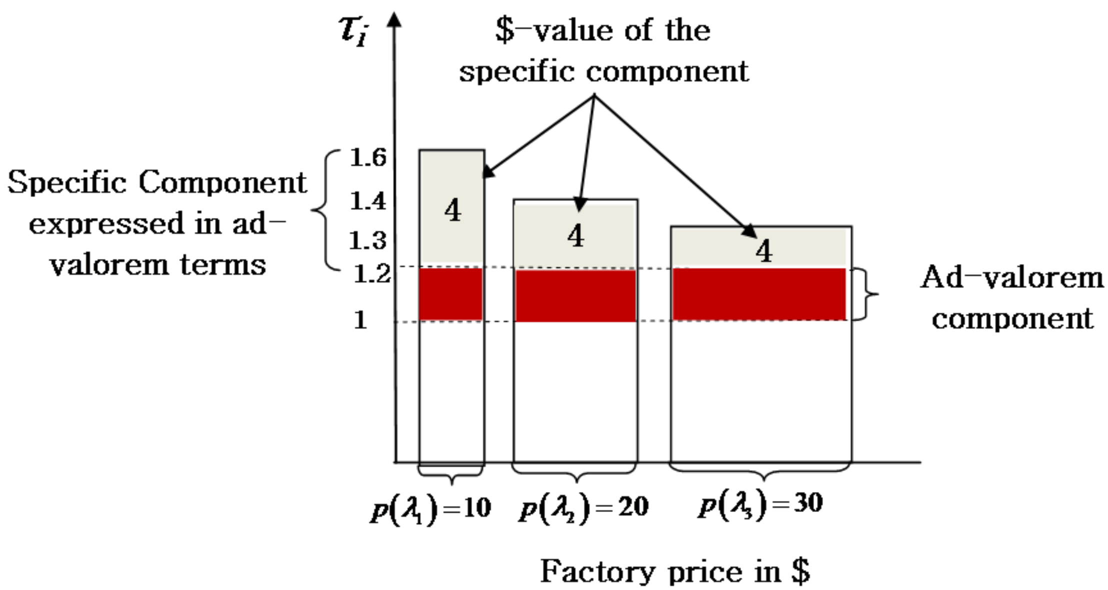

Figure 1: Ad-valorem and Specific Components in the Augmented Iceberg Transportation Cost

The fixed cost of producing the first quality level is country-sector-specific and is denoted by F_{gi}. The firms that are willing to produce multiple qualities have to incur an additional fixed cost that is set to zero for all subsector θ's varieties and is prohibitively high for all subsector γ's varieties.

2.3 Transportation cost

It is difficult to derive a structural functional form of the transportation cost. For example, if we focus on the vessel mode of transportation, international shipping is a sophisticated technology that includes both fixed and variable cost components. The fixed cost component is a function of the port infrastructure, where the variable cost depends on distance, volume of trade, and good-specific characteristics (Hummels, Lugovskyy, and Skiba (2009)). Our model ignores the fixed cost of transportation, but allows the variable cost to have both ad-valorem and specific components while at the same time, attempting to preserve the analytical simplicity and tractability of the Samuelson iceberg functional form. In allowing the variable cost to have both components, we denote the ad-valorem part of the transportation cost of all of sector g's varieties from j to i as a_{gij} and the specific part as s_{gij}. Transportation cost is perfectly competitive, and transporters set the

and Klenow (2005).

schedule of transportation costs in ad-valorem terms:

$$\tau_{vij}\left(\lambda_{vij}\right) = 1 + a_{gij} + s_{gij}/p_{vij}\left(\lambda_{vij}\right) \tag{5}$$

where $\tau_{vij}\left(\lambda_{vij}\right) - 1$ is the amount of variety v of quality λ_{vij} required by transporters to ship one unit of this variety from j to i, and $p_{vij}\left(\lambda_{vij}\right)$ is the factory-gate (i.e., net of transportation cost) price of this variety (see also Figure 1).

Transporters post their schedules before observing the actual prices. In particular, transporters and producers are engaged in a two-stage price-setting game. A transporter moves first by posting the transportation cost schedule for every quality level λ_{vij} and every route ij. To this goal, he considers the best response of a producer, that is, how the producer will respond after observing the schedule of $\tau_{vij}\left(\lambda_{vij}\right)$. In the second state, a producer takes the transportation cost schedule as given and chooses the profit-maximizing delivered price P_{vij}.

2.4 Market equilibrium

In this section, we focus on the equilibrium prices, quantities, and quality levels chosen by sector g's firms of country-exporter j. For brevity, we omit exporter and sector subscripts. In what follows, we use index v for the varieties produced by single-quality firms in subsector γ and r for the varieties produced by multi-quality firms in subsector θ.

We start by calculating the best response of producers in single-quality subsector γ. For every destination i, the producer of variety v observes the schedule of transportation costs for every quality level $\lambda_v \in \left[\underline{\lambda}, \overline{\lambda}\right]$. Using this information, producers maximize their profit function with respect to the delivered prices to each destination with the positive demand for variety v, $\{P_{vi} : i \in \Psi\}$ and single quality λ_v:

$$\max_{\{P_{vi}:i\in\Psi\},\lambda_v} \pi_v = \sum_{i\in\Psi} X_{vi}\left[P_{vi} - wb_v\tau_{vi}\right] - F \qquad v \in \gamma \tag{6}$$

where X_v is the total delivered quantity, P_{vi} is the delivered price of the differentiated variety v to country i, and τ_{vi} is the corresponding iceberg transportation cost. From the first-order conditions with respect to P_{vi},

$$\frac{\partial \pi_v}{\partial P_{vi}} = \frac{\partial X_{vi}}{\partial P_{vi}}(P_{vi} - wb_{vi}\tau_{vi}) + X_{vi} = 0 \qquad \forall i \in \Psi$$

we obtain something reminiscent of the Krugman (1980) style model's delivered price:

$$P_{vi} = \frac{\sigma}{\sigma - 1}\left[wB\exp\left(\frac{\lambda_v}{\beta}\right)\right]\tau_{vi} \qquad\qquad i \in \Psi \tag{7}$$

which is a product of monopolistic markup, marginal cost of production (in square brackets), and iceberg transportation cost τ_{vi}. The corresponding factory-gate price is then

$$p_{vi} = \frac{\sigma}{\sigma - 1}\left[wB\exp\left(\frac{\lambda_v}{\beta}\right)\right] \qquad\qquad i \in \Psi \tag{8}$$

By plugging the factory-gate price into equation (5), we solve for the equilibrium transportation cost expressed as a Samuelson iceberg:

$$\tau_{vi} = 1 + a_i + \frac{\sigma - 1}{\sigma}\frac{s_i}{wB\exp\left(\lambda_v/\beta\right)} \qquad\qquad i \in \Psi \tag{9}$$

The above solutions (8) and (9) are unique for the given destination i and quality level λ_v.[18]

Note that while the factory-gate price is a function of quality, it is not directly dependent on the destination specific transportation cost. Thus, a firm in subsector γ that produces single-quality variety (due to the prohibitively high fixed cost of multiple qualities) will set the same symmetric factory-gate price for all destinations:

$$p_{vi}\left(\lambda_v\right) = p_v\left(\lambda_v\right) = \frac{\sigma wB}{\sigma - 1}\exp\left(\lambda_v/\beta\right) \qquad\qquad \forall v \in \gamma; i \in \Psi \tag{10}$$

It is important to note further that even though producers are free to charge destination specific factory-prices (i.e., to price-discriminate across locations), the "no arbitrage" condition holds in sector γ: for a given quality level, the equilibrium factory-price is independent of the transportation cost and is the same across destinations. Therefore, despite the specific component of the transportation cost, the analytical convenience of the Samuelson iceberg is preserved.[19]

Next, we proceed with the first-order condition with respect to the quality level λ_v:

$$\frac{\partial \pi_v}{\partial \lambda_v} = \sum_{i\in\Psi}\left[\frac{\partial X_{vi}}{\partial \lambda_v}\left(P_{vi} - wb_v\tau_{vi}\right) - X_{vi}w\left(\frac{\partial b_v}{\partial \lambda_v}\tau_{vi} + b_v\frac{\partial \tau_{vi}}{\partial \lambda_v}\right)\right] = 0 \qquad\qquad \forall v \in \gamma.$$

Given the utility function (1), transportation costs (9), and equilibrium price (10), the above formula

[18] The factory-gate price is a monotonically increasing function of quality; thus, there is a unique factory-gate price for each quality. The expected factory price is unique for each λ for the same reason, which makes the equilibrium transportation cost unique as well.

[19] This property is achieved due to the two-stage pricing mechanism in which transporters move first and producers take the transportation cost schedule as given.

can be simplified as follows:[20]

$$\frac{\partial \pi_v}{\partial \lambda_v} = \frac{\sigma - 1}{\sigma} \sum_i P_{vi} X_{vi} \left(\frac{\delta_i}{\lambda_v} - \frac{1 + a_i}{\beta \tau_{vi}} \right) = 0,$$

from which we find the equilibrium quality:[21]

$$\lambda_v = \beta \frac{\frac{\sum_{i\in\Psi} P_{vi} X_{vi} \delta_i}{\sum_{i\in\Psi} P_{vi} X_{vi}}}{\frac{\sum_{i\in\Psi} P_{vi} X_{vi} (1+a_i)/\tau_{vi}}{\sum_{i\in\Psi} P_{vi} X_{vi}}} \equiv \beta \frac{\bar{\delta}}{\overline{(1+a)/\tau_v}} \qquad \forall v \in \gamma. \tag{11}$$

While the above result does not provide an explicit solution for the equilibrium quality level (P_{vi}, X_{vi}, and τ_{vi} are functions of quality), it provides an important intuitive interpretation: the equilibrium quality level of single-quality firms increases in the technological parameter β and the *multilateral* (weighted average) intensity of preference for quality $\bar{\delta}$, and decreases in the *multilateral* (weighted average) ratio of the ad-valorem part of the iceberg over the total iceberg transportation cost, $\overline{(1+a)/\tau_v}$.

Subsector θ's firms, on the other hand, are able to adjust the quality for each destination. Hence, they will maximize their profit with respect to the destination-specific quality,

$$\max_{\{P_{ri}, \lambda_{ri}: i\in\Psi\},} \pi_r = \sum_{i\in\Psi} X_{ri} \left[P_{ri} - w b_{ri} \tau_{ri} \right] - F \qquad \forall r \in \theta.$$

Since firms can choose destination-specific quality, and the marginal cost does not depend on the total level of output, the profit-maximizing price and quality for each destination are independent of the price and quality levels for other destinations. The first-order conditions are given by the following:

$$\frac{\partial \pi_r}{\partial P_{ri}} = \frac{\partial X_{ri}}{\partial P_{ri}} (P_{ri} - w b_{ri} \tau_{ri}) + X_{ri} = 0 \qquad \forall r \in \theta, i \in \Psi$$

and

$$\frac{\partial \pi_r}{\partial \lambda_{ri}} = \frac{\partial X_{ri}}{\partial \lambda_{ri}} (P_{ri} - w b_v \tau_{ri}) - X_{ri} w \left(\frac{\partial b_{ri}}{\partial \lambda_{ri}} \tau_{ri} + b_{ri} \frac{\partial \tau_{ri}}{\partial \lambda_{ri}} \right) = 0 \qquad \forall r \in \theta, i \in \Psi.$$

The equilibrium price and quality levels in the multiple-quality subsector θ are then

$$p_{ri}(\lambda_{ri}) = \frac{\sigma w B}{\sigma - 1} \exp(\lambda_{ri}/\beta) \qquad \forall r \in \theta; i \in \Psi \tag{12}$$

[20] More details can be found in the Appendix for reviewers, available at http://www.uwyo.edu/askiba
[21] The second-order conditions are provided in the Appendix.

and

$$\lambda_{ri} = \beta\delta_i \left[(1+a_i)/\tau_{ri}\right]^{-1} \qquad r \in \theta; i \in \Psi. \tag{13}$$

As we can see from the equation above, the equilibrium quality increases in the *importer's* intensity of preference for quality and decreases in the *bilateral* ad-valoremness of the transportation cost.

Next, we recall that consumers allocate a constant expenditure share to subsectors γ and θ according to the properties of the Cobb-Douglas utility function (1):

$$\left(\sum_{v\in\gamma}\left(\lambda_v^{\delta_i}X_{vi}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\left(\sum_{v\in\gamma}\frac{P_{vi}^{1-\sigma}}{\lambda_v^{\delta_i(1-\sigma)}}\right)^{\frac{1}{1-\sigma}} = (1-k)\,\eta_i w_i L_i$$

$$\left(\sum_{r\in\theta}\left(\lambda_{ri}^{\delta_i}X_{ri}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}\left(\sum_{r\in\theta}\frac{P_{ri}^{1-\sigma}}{\lambda_{ri}^{\delta_i(1-\sigma)}}\right)^{\frac{1}{1-\sigma}} = k\eta_i w_i L_i.$$

Based on this property, in the symmetric equilibrium, the per-variety quantities delivered to location $i \in \Psi$ are given by

$$X_{vi} = \frac{(1-k)\,\eta_i w_i L_i}{N_\gamma P_{vi}} \qquad \forall \text{v} \in \gamma; \qquad\qquad X_{ri} = \frac{k\eta_i w_i L_i}{N_\theta P_{ri}} \qquad \forall r \in \theta, \tag{14}$$

where N_γ and N_θ are the equilibrium numbers of the varieties in sub-sectors γ and θ, respectively. Given the quality level, the equilibrium number of the varieties and quantity per variety in each subsector can be uniquely determined from the demand functions (14) and zero-profit conditions below:

$$\sum_{i\in\Psi} X_{vi}\left(P_{vi} - wb_v\tau_{vi}\right) = F \qquad \forall v \in \gamma; \qquad\qquad \sum_{i\in\Psi} X_{ri}\left(P_{ri} - wb_{ri}\tau_{ri}\right) = F \qquad \forall r \in \theta.$$

2.5 Predictions

In this section, we explore the properties of the average factory-gate price of exports from country j to country i in sector g. As in the previous subsection, for brevity, we omit exporter-sector index jg. The price is a weighted average of the single-quality and multi-quality factory gate prices (defined by equations (8) and (12)), where the weights are the total quantities of each type shipped to each destination:

$$\overline{p}_i \equiv \frac{N_\gamma p_v X_{vi} + N_\theta p_{ri} X_{ri}}{N_\gamma X_{vi} + N_\theta X_{ri}} \qquad \forall i \in \Psi.$$

Using symmetry and the equilibrium values of the prices and quantities of single-quality firms (equations (8) and (14)) and of multi-quality firms (equations (10) and (14)), the above formula can be modified as follows:

$$\overline{p_i} = \frac{\sigma w B}{\sigma - 1} \exp\left(\frac{\lambda_v}{\beta}\right) \frac{1 + (1-k)\,\tau_{ri}/\left(k\tau_{vi}\right)}{\exp\left[\left(\lambda_v - \lambda_{ri}\right)/\beta\right] + (1-k)\,\tau_{ri}/\left(k\tau_{vi}\right)} \qquad \forall i \in \Psi, v \in \gamma, r \in \theta.$$

After plugging in the equilibrium quality levels for λ_v and λ_{ri} (equations (9) and (13)) and rearranging the terms, we get

$$\overline{p_i} = \underbrace{\frac{\sigma w B}{\sigma - 1} \exp\left(\frac{\overline{\delta}}{\overline{(1+a)/\tau_v}}\right)}_{\text{sector-exporter}} \underbrace{\frac{\frac{1-k}{k}\frac{\tau_{ri}}{\tau_{vi}} + 1}{\frac{1-k}{k}\frac{\tau_{ri}}{\tau_{vi}} + \exp\left(\frac{\overline{\delta}}{\overline{(1+a)/\tau_v}} - \frac{\delta_i}{(1+a_i)/\tau_{ri}}\right)}}_{\text{sector-importer-exporter}}. \tag{15}$$

Note that the first part of equation (15) contains the sector's average values; thus, it is the same for all destinations i to which a given exporter ships the sector's varieties, while the second part varies with the destination, since it depends on country i's parameters.

Definition 1. *Let us define subsector γ's Multilateral Quality Compensation (MQC) term as the ratio of the weighted averages of the intensity of the preference for quality $\overline{\delta}$ to the ad-valoremness of the transportation cost from country j to country i, $\overline{(1+a)/\tau_v}$:*

$$\text{MQC} \equiv \overline{\delta}\left[\overline{(1+a)/\tau_v}\right]^{-1} = \frac{\sum_{i\in\Psi} P_{vi} X_{vi} \delta_i}{\sum_{i\in\Psi} P_{vi} X_{vi}} \left[\frac{\sum_{i\in\Psi} P_{vi} X_{vi}\,(1+a_i)/\tau_{vi}}{\sum_{i\in\Psi} P_{vi} X_{vi}}\right]^{-1}.$$

Proposition 1. *Ceteris paribus, the sector-level factory-gate price from a given exporter to all destinations increases in the MQC term.*

Proof. From equation (15) $\left.\frac{\partial \overline{p}_i}{\partial \text{MQC}}\right|_{\frac{\delta_i}{(1+a_i)/\tau_{ri}} = Const} > 0 \qquad \forall i \in \Psi.$ □

Intuitively, since quality level depends on multilateral factors (embedded in MQC), so does the sector-level factory-price. This term captures the combined effect of the preference for quality and the Alchian-Allen effect on the quality of exports. Moreover, the intuitive interpretation of the effect of the ad-valoremness term, $\overline{(1+a)/\tau_v}$, on the price is as follows: the larger the share of the ad-valorem component (and thus, the smaller the share of the specific component) in the total transportation cost is, the smaller the compensating effect of quality and price on the delivered price is, and consequently, the weaker are the incentives to upgrade quality. In the limit, when the transportation cost is purely ad-valorem, $\overline{(1+a)/\tau_v} = 1$, the quality and price do not depend on the multilateral transportation costs.

Proposition 2. *Ceteris paribus, the sector-level factory-gate price from a given exporter to country i increases in country i's ratio of intensity of preference for quality to the ad-valoremness of the* *transportation cost.*

Proof. From equation (15) $\left.\frac{\partial \overline{p}_i}{\partial \frac{\delta_i}{(1+a_i)/\tau_{ri}}}\right|_{\text{MQC}=Const} > 0 \qquad \forall i \in \Psi.$ □

The intuition of this proposition is similar to that outlined above, with the major difference being that for multi-quality varieties, multi-lateral factors do not matter, since they are able to adjust quality separately for each destination.

3 Empirics

3.1 Data

Our trade data comes from the BTI trade database for 1999–2004. The data includes product level information on imports to seven Latin American countries (Argentina, Brazil, Chile, Columbia, Ecuador, Peru, and Uruguay), and therefore, many importer-exporter pairs. We employ data on Latin American imports in each year t, disaggregated by importer i, exporter j, and product g. A product g is a Harmonized System 6-digit category, with roughly 5,000 6-digit product categories. We observe value, weight, duties paid, insurance, and shipment charges for each $ijgt$ observation.

One important limitation of the product level data set such as the one used in this study is that even at the 6-digit level of disaggregation, categories subsume a substantial amount of variation in characteristics that are not captured by the HS 6-digit classification category. Those features may include brand, fabric design, color, navigation package in a car, or printing speed for a printer. This limitation has been explored by Moralez and Sheu (2010) and Blonigen and Soderbery (2010) in some narrowly specialized and highly disaggregated data sets. What those studies reveal that is relevant to our study is that compositional effects are present and must to be taken into account to the extent that they affect the question at hand. In our case, we need to explicitly account for the quality compositional effects that may occur on the sub-product level. Informed by the theory, we control for quality composition with a set of product-exporter-importer specific quality composition shifters.

While it is not the most detailed data set that can be collected, the 6-digit detail data that we use offer several distinct advantages. First, even at the 6-digit level, the products are identified with adequate detail to mitigate compositional effects. In other words, the high price of "PRINTING INK, BLACK" (HS 6-digit category "321511") is a better indication of quality than, for example, the higher price of the more aggregated "TANNING & DYE EXT ETC; DYE, PAINT, PUTTY ETC; INKS" (HS 2-digit category "32"). The latter could arise from a shift in the composition of trade toward more expensive types of products within the given HS 2-digit category. Second, the coverage of the HS 6-digit trade data is much more extensive than that of one of more specialized data sets. Third, our data contains reasonable measures of transportation cost and insurance, both of which are important for the identification of quality composition.

The data on the value of bilateral trade for the rest of the world comes from the World Integrated Trade Solution data set for the years 1999–2004. However, this data does not have insurance and transportation costs. The data on the GDP per capita and population size are from the World Development Indicators (1999–2004), and the bilateral great circle distances between the capital cities of trading partners are from Head and Mayer (2002).

3.2 Average price

At this point, we formulate the estimating equation of the observed average price. The main premise of our approach is that the price contains information on the quality of the traded goods. To measure prices, we calculate the unit values as value-to-weight ratios. Equation (15) shows that the logarithm of price can be linearly decomposed into the exporter specific and exporter-destination specific components for each product g in a given year t. We label the components correspondingly as $\ln p_{jgt}$ and $\ln p_{ijgt}$ to get

$$\ln \bar{p}_{ijgt} = \ln p_{jgt} + \ln p_{ijgt} \tag{16}$$

Our empirical exercise is complementary to Hummels and Skiba (2004), who focused on the destination variation for a given exporter-product pair and controlled for the exporter-product price term $\ln p_{jgt}$ by mean-differencing all variables with respect to exporter-product means. We, on the other hand, aim to explain the exporter-specific quality component. To this end, we log-linearize equation (10), where we control for country-specific variation in wages and technologies with the GDP and GDP per capita of the exporter, and introduce a fixed effect for the product and year:

$$\ln p_{jgt} = \alpha_{gt} + \alpha_1 MQC_{jgt} + \alpha_2 GDP_{jt} + \alpha_3 \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right) + \nu_{jgt} \tag{17}$$

where POP_{jt} is the population of exporter j in year t. Based on the previous research and our model, the destination-specific component of the average price can vary due to the pricing-to-market, compositional Alchian-Allen effect, and quality-tailoring. Our theory focuses on the quality-tailoring aspect; however, the variation in the unit values observed in our data probably reflects the other above mentioned reasons as well. This is why we intentionally avoid forcing the specific functional form derived from our model while estimating the destination-specific price component, and instead allow for more flexibility in our estimation equation to capture other channels:

$$\ln p_{ijgt} = \alpha_{igt} \quad +\alpha_4 \ln\left(\frac{FRT_{ijgt}}{WGT_{ijgt}}\right) + \alpha_5 \ln\left(INS_{ijgt}\right) + \alpha_6 \ln\left(DIST_{ij}\right) + \nu_{ijgt} \tag{18}$$

where FRT_{ijgt} is the total freight bill, WGT_{ijgt} is the total weight, INS_{ijgt} is the insurance bill as a share of the trade value, and $DIST_{ij}$ is the distance between i and j. Combining equations (17) and (18) produces the main estimating equation.

$$\begin{aligned}\ln \bar{p}_{ijgt} = \alpha_{igt} \quad & +\alpha_1 MQC_{jgt} + \alpha_2 GDP_{jt} + \alpha_3 \ln\left(\frac{GDP_{jt}}{POP_{jt}}\right) \\ & +\alpha_4 \ln\left(\frac{FRT_{ijgt}}{WGT_{ijgt}}\right) + \alpha_5 \ln\left(INS_{ijgt}\right) + \alpha_6 \ln\left(DIST_{ij}\right) + \nu_{ijgt}\end{aligned} \tag{19}$$

where $\ln \bar{p}_{ijgt}$ is measured as the value of trade VAL divided by the total weight: $\frac{VAL_{ijgt}}{WGT_{ijgt}}$. The set of product-year effects α_{gt} is absorbed by the set of more detailed product-year-destination effects α_{igt}.

3.3 Construction of the Multilateral Quality Compensation term

In order to construct the MQC term as defined in Definition 1, we need to know the values of bilateral trade, domestic sales, the shares of the ad-valorem component in the transportation cost, and the quality preference parameter. The values of international trade are observed, but the others are not; therefore, they must be constructed.

Constructing the intensity of the preference for quality

Following Hallak (2006) and others, we assume that the intensity of the preference for quality can be approximated by the logarithm of the importer's GDP per capita:

$$\delta_{it} = \alpha_7^{gt} \ln\left(\frac{GDP_{it}}{POP_{it}}\right)$$

The demand for different goods can exhibit varying degrees of sensitivity to income in the destination market. The product specific shifter α_7^{gt} will be taken outside the summation sign and absorbed into the product-destination-year effect α_{igt}.

Approximating the ad-valorem share of the transportation cost

Calculating the exact empirical equivalent of the ad-valorem share of transportation cost $\frac{1+a_{ijgt}}{\tau_{ijgt}}$ is complicated by several factors. The most important of them is data availability. The cost of shipping is generally not known for all trading partners worldwide. In cases where the transportation cost is reported, we usually observe the total freight bill and not its components. The complications do not stop here; even if we know the amount of the total freight bill along with its components, there is no practical reason for the shipping cost data to be classified on the basis of their correlation with the unit values of the shipped goods. Lacking the data on the relative size of the ad-valorem component in the total iceberg equivalent of the transportation cost, we follow the conventional wisdom and assume that the main shifter of the specific part in the transportation cost is the distance between partners. Specifically, we assume that

$$\frac{1 + a_{ijgt}}{\tau_{ijgt}} = \frac{A_{gt}}{\ln DIST_{ij}} \tag{20}$$

where A_{gt} is the product specific transportation cost shifter at time t. The above assumption is credible for a number of reasons. First, the assumption follows the original logic of the Alchian-Allen effect that distance increases the distortion to prices caused by the transportation cost. Intuitively, we think that the components of the transportation cost that are related to the bilateral distance increase the transportation cost of all cheap and expensive goods; thus, longer distances increase the role of the non-price related determinants of the transportation cost. Second, Irarrazabal et al. (2010) structurally estimated the size of the specific trade cost and showed that it is positively correlated with the bilateral distance. To further support the above assumption, we perform two additional auxiliary tests. For the first test, we use the insurance fee to proxy for the ad-valorem component of the total trade cost. The insurance fees are believed to be related more to the value of the shipped good rather than to the other shipping cost factors. Thus, we assume that insurance is the only ad-valorem factor and estimate the share of the ad-valorem component in the total iceberg, $(1 + a_{ijgt})/\tau_{ijgt}$, as follows:

$$\frac{1 + INS_{ijgt}/VAL_{ijgt}}{1 + INS_{ijgt}/VAL_{ijgt} + FRT_{ijgt}/VAL_{ijgt}} = \alpha_{gt} + \alpha_8 \ln DIST_{ij} + \varepsilon_{ijgt}$$

The coefficients of the above equation are estimated by ordinary least squares with heterskedasticity robust standard errors. We obtain a statistically significant and negative value of α_8, which indicates that the share of the ad-valorem part measured by insurance is decreasing in distance. The results are encouraging, even though the dependent variable could miss some other ad-valorem components of the transportation cost.

For the second test, we estimate how the relationship between the transportation cost and value of the traded good depends on the bilateral distance. We estimate the coefficients of the equation below by ordinary least squares with heteroskedasticity robust standard errors.

$$\ln\left(\frac{FRT_{ijgt}}{VAL_{ijgt}}\right) = \alpha_{gt} \quad +\alpha_9 \ln DIST_{ij} + \alpha_{10} \ln\left(\frac{VAL_{ijgt}}{WGT_{ijgt}}\right) \\ +\alpha_{11} \ln\left(\frac{VAL_{ijgt}}{WGT_{ijgt}}\right) \times \ln DIST_{ij} + \alpha_{12} \ln SCALE_{ijgt} + \nu_{ijgt} \tag{21}$$

Since the price is clearly endogenous to the transportation cost, we instrument the unit values with the importer's GDP per capita, and similarly instrument the interaction term with distance. The elasticity of the transportation cost with respect to the unit value indicates the degree to which the transportation cost is ad-valorem or specific. In the case of traditional iceberg, the transportation cost varies with the price one-to-one. In the case of pure specific cost, the transportation cost does not depend on the value of the shipped good. Anything between zero and one indicates that the transportation cost is not pure iceberg, and the closer the coefficient is to one, the smaller the specific component of transportation cost is. See the discussion in Hummels and Skiba (2004) for more details. Since the effect of the unit value on the unit transportation charge is given by

$$\alpha_{10} + \alpha_{11} \ln DIST_{ij},$$

the coefficient α_{11} on the cross term indicates whether distance effects the extent to which transportation cost resembles iceberg. The estimate of the direct effect α_{10} is positive and smaller than one, and the estimate of the interaction term of the unit value with distance α_{11} is negative. The negative interaction term with distance means that with distance, the effect of the unit value is moving away from one, i.e., the transportation cost is farther from iceberg. Furthermore, the distance makes the elasticity of the unit freight charge with respect to the unit value less like iceberg and more like the specific transportation cost.

Constructing the domestic volume of trade

The proper construction of the MQC term requires data on domestic sales that would match the product-exporter dimensionality of our data. This data is generally not available for all exporters. In order to construct the domestic values of trade, we estimate a traditional gravity model of trade and predict domestic quantity based on domestic GDP and domestic internal distance. Internal distance is taken from Head and Mayer (2002). From the literature on the border effect and home bias, we know that domestic trade is larger than what is predicted by gravity, so we experiment with assigning larger weights to the domestic GDP and internal distance when predicting domestic sales. However, we find that the constructed MQC term is only marginally affected by accounting for the home bias effect.

3.4 Endogeneity

There are two sources of endogeneity in equation (19): (1) the freight rate generally depends on the value of the shipped goods, and (2) MQC is a function of quality. First, the freight rate depends on price, distance, scale, and product specific characteristics. Among those variables, scale is the only exogenous variable that can be used to instrument for freight rate and yet be independent of quality. We construct the scale variable as the total value of trade between i and j at time t in the 2-digit category to which g belongs, less the value of trade for the $ijgt$ observation:

$$SCALE_{ijgt} = \sum_{h \in HS2_g} P_{ijht} X_{ijht} - P_{ijgt} X_{ijgt} \qquad HS2_g = \{HS2 : g \in HS2\}$$

The scale variable is exogenous by construction, as it excludes the $ijgt$ variation in the quantity and price. Contrary to Hummels and Skiba (2004), distance is not used as the instrument of the specific transportation cost, since, as suggested by Baldwin and Harrigan (2007), distance might affect the average product quality even under the ad-valorem transportation cost, through the self-selection of higher quality exporters.

Second, MQC is constructed using trade values that are a function of product prices and, thus, depend on the product-exporter specific quality. This requires an instrument for MQC that would exclude the product-exporter specific quality from the values of trade. Note that the product-exporter-destination specific component of quality is explicitly accounted for by the freight, distance, and insurance variables in equation (19). To remove exporter-specific quality variation from the observed trade values, we estimate the trade value equation, explicitly controlling for product-exporter specific quality, and then use only the variables that are not related to the product-exporter specific quality shifters. Following our model's predictions about the effect of quality on the value of trade, we estimate the following trade flow equation

$$\ln \mathrm{VAL}_{ijgt} = \alpha_{jgt} + \alpha_{12} \ln GDP_{it} + \alpha_{13} \ln \left(\frac{GDP_{it}}{POP_{it}} \right) + \alpha_{14} \ln (DIST_{ij}) + \nu_{ijgt} \tag{22}$$

The exporter's quality component is controlled for by α_{jgt}. In equation (22), bilateral distance can affect the bilateral value of trade through two channels. First, the distance is used to construct MQC, which is product-exporter specific and is controlled for by the α_{jgt} dummy along with other exporter product quality factors. Second, distance affects quality through the destination specific transportation friction. We condition on both channels explicitly, leaving only the trade reducing effect of distance in the above equation. The quality component is absorbed by the α_{jgt} dummy. The other part is explicitly accounted for by the distance, freight, and insurance variable in equation (19), resulting in an orthogonal error term.

In sum, we construct $\widehat{MQC}_{jt}$ based on Definition 1, where export volumes $P_{ijgt}X_{ijgt}$ terms are replaced by $\widehat{VAL}_{ijgt}$ constructed based on the estimated coefficients of equation (22) as

$$\ln \widehat{\mathrm{VAL}}_{ijgt} = \hat{\alpha}_{12} \ln GDP_{it} + \hat{\alpha}_{14} \ln \left(DIST_{ij}\right) \tag{23}$$

Similar to the aforementioned Market Potential Index, the instrument $\widehat{MQC}_{jt}$ can be thought of as the potential MQC because it depends only on the exogenous geography factors: the distance and GDPs of the trading partners.

Based on the common battery of tests, the instruments are strong and valid. The tables presenting the estimation results presented in the next section report the p-values of the LM test for the underidentification of all instrumented variables. In all specifications, the null of underidentification is safely rejected with high precision. Testing for the underidentification of each instrumented variable separately produces the same result. We also report the Cragg and Donald (1993) F-statistics of the test for weak identification of instrumented variables, and the high values of the F-statistics suggest the strength of the instruments. The test for overidentification is not carried out because the instrumental variables are exactly identified.

3.5 Results

This section presents the estimation results of equation (19). Table 1 shows the results for all countries broken down by whether the exporter belongs to the OECD. OECD membership is used as a proxy for development and presumably indicates a comparative advantage in quality. The signs of the coefficients on the Multilateral Quality Compensation, freight rate, and transportation insurance variables coincide with our theoretical predictions of Propositions 1 and 2. The magnitude of the MQC coefficient in the non-OECD sample is 24% higher than that in the OECD sample, indicating that geographic position affects export prices more strongly for non-OECD countries. There are several potential explanations for the effect. First, as suggested by Hummels, Lugovskyy, and Skiba (2009), non-OECD countries are facing higher freight rates; thus, the same weighted distance in MQC corresponds to lower ad-valoremness in the non-OECD sample. This creates stronger incentives to upgrade quality due to the supply-side Alchian-Allen effect. Second, the variable cost of quality upgrading might be higher for developing countries, and thus, the same increase in quality translates to relatively higher prices for developing countries. Finally, the producers of differentiated goods in developing countries might take export markets more seriously than their counterparts in developed countries and, thus, have a stronger response to multilateral geographic factors.[22]

[22]For example, some firms in developing countries are shown to serve as export platforms, in which case, they devote most of their output to exports. Naturally, those producers are more affected by the multilateral demand for their output.

Table 1: Determinants of export quality by OECD membership.

	1	2	3
OECD	All	Yes	No
MQC_{jt}	0.0049	0.0033	0.0041
	(0.0005)**	(0.0009)**	(0.0011)**
$\ln f_{ijgt}$	0.5732	0.5579	0.5728
	(0.0063)**	(0.0087)**	(0.0143)**
$\ln INS_{ijgt}$	-0.1849	-0.1745	-0.2018
	(0.0023)**	(0.0030)**	(0.0049)**
$\ln GDP_{jt}$	-0.0708	-0.0725	-0.0790
	(0.0030)**	(0.0046)**	(0.0055)**
$\ln \frac{GDP_{jt}}{POP_{jt}}$	0.1623	0.2311	0.0926
	(0.0026)**	(0.0044)**	(0.0056)**
$\ln DIST_{ij}$	-0.0758	-0.0142	-0.1087
	(0.0019)**	(0.0059)*	(0.0025)**
OECD	0.0366		
	(0.0053)**		
u.i.p-val[a]	0.000	0.000	0.000
C-D F-stat[b]	6261.4	3383.6	987.1
N of igt	48728	48489	43309
Obs.	743060	504203	234729

Notes: Standard errors in parantheses. * significant at 5%; ** significant at 1%. All specifications include importer-product-year fixed effects α_{igt}. All specifications are estimated using 2SLS procedure implemented for STATA as `xtivreg2` by Schaffer (2005). [a]- p-value of the LM test for underidentification of all instrumented variables. [b]- Cragg and Donald (1993) F-statistics of test for weak identification of instrumented variables. The test for overidentification is not carried out because the instrumental variables are exactly identified.

Interestingly, the coefficient on $\ln DIST_{ij}$ is negative. In other words, after accounting for the transportation cost, the bilateral distance has a negative effect on quality. At first sight, it appears that this finding is at odds with the previous findings of Baldwin and Harrigan (2007). However, there is no contradiction once one takes into account the possibility that distance creates an ad-valorem as well as a specific trade barrier. Note that in Baldwin and Harrigan (2007), distance affects the average quality by restricting the set of exporters. This effect would occur whether distance created an ad-valorem or a specific barrier to trade. In either case, foreign consumers face a higher price. In our case, the unit-freight variable $\ln(FRT_{ijgt}/WGT_{ijgt})$ captures the effect of distance on price through the traditional Alchian-Allen channel. After the effect of transportation cost is removed, the remaining negative partial effect of distance indicates that the effect of distance on price that is not accounted for by the transportation cost is ad-valorem in nature. The effect of distance is 7.8 times higher in the case of non-OECD exporters, indicating a much higher effect of the ad-valorem distance net of transportation cost effects.

The coefficient on the exporter's GDP per capita is difficult to interpret because it captures two separate effects: the cost effect and the quality upgrading effect. Countries with a higher per capita GDP have a higher cost of production, but are more productive. The effect of the exporter GDP per capita is higher for OECD countries, indicating that among OECD countries, those with a higher income likely charge higher prices because in addition to incurring higher cost, they also have greater potential to upgrade.

Finally, the OECD dummy is positive and significant, indicating that when controlling for other factors, OECD countries' export prices are 3.7% higher than those of non-OECD countries.

Quality upgrading: differentiated vs. homogeneous products

We estimate equation (19) by separating it into differentiated, reference, and homogeneous groups according to Rauch (1999). The results are presented in Table 2. Column 1 of this table is the same as that in Table 1, shown for comparison. The differentiated product breakdown captures some unobserved characteristics of the product that makes the quality more susceptible to change. The results described in Table 2 provide both direct and indirect support for *Proposition* 1. In particular, as stated in *Proposition* 1, the MQC index increases the export prices of the differentiated goods. At the same time, MQC has no statistically significant effect on the export prices of reference and homogeneous goods. We interpret this as evidence that MQC increases the quality rather than other components of the price, since by the nature of the products, quality upgrading is much less expected for reference and homogeneous goods.

As in Table 1, the signs of all other coefficients coincide with our predictions. Moreover, since homogeneous goods by definition have a much higher price elasticity of demand, one would expect

Table 2: Determinants of export quality by product differentiation.

	1	2	3	4
Rauch	All	Diff	Ref	Homo
MQC_{jt}	0.0049	0.0056	0.0009	0.0093
	(0.0005)**	(0.0006)**	(0.0017)	(0.0113)
$\ln f_{ijgt}$	0.5732	0.5600	0.6110	0.8565
	(0.0063)**	(0.0069)**	(0.0174)**	(0.1443)**
$\ln INS_{ijgt}$	-0.1849	-0.1898	-0.1675	-0.2719
	(0.0023)**	(0.0025)**	(0.0064)**	(0.0487)**
$\ln GDP_{jt}$	-0.0708	-0.0765	-0.0487	-0.0729
	(0.0030)**	(0.0033)**	(0.0082)**	(0.0492)
$\ln \frac{GDP_{jt}}{POP_{jt}}$	0.1623	0.1758	0.0998	0.0745
	(0.0026)**	(0.0031)**	(0.0053)**	(0.0180)**
$\ln DIST_{ij}$	-0.0758	-0.0808	-0.0461	-0.1242
	(0.0019)**	(0.0020)**	(0.0055)**	(0.0275)**
OECD	0.0366	0.0338	0.0583	0.0628
	(0.0053)**	(0.0060)**	(0.0122)**	(0.0734)
u.i.p-val^a	0.000	0.000	0.000	0.000
C-D F-stat^b	6261.4	5600.9	656.8	8.4
N of igt	48728	35229	9958	738
Obs.	743060	556402	131838	7129

Notes: Standard errors in parantheses. * significant at 5%; ** significant at 1%. All specifications include importer-product-year fixed effects α_{igt}. All specifications are estimated using 2SLS procedure implemented for STATA as `xtivreg2` by Schaffer (2005). ^{a}- p-value of the LM test for underidentification of all instrumented variables. ^{b}- Cragg and Donald (1993) F-statistics of test for weak identification of instrumented variables. The test for overidentification is not carried out because the instrumental variables are exactly identified.

Table 3: Determinants of export quality by OECD membership and product differentiation.

	1	2	3	4	5	6
OECD	Yes	No	Yes	No	Yes	No
Rauch	Diff	Diff	Ref	Ref	Homo	Homo
MQC_{jt}	0.0048	0.0054	0.0046	-0.0145	0.0016	-0.0049
	(0.0010)**	(0.0011)**	(0.0028)	(0.0042)**	(0.0252)	(0.0164)
$\ln f_{ijgt}$	0.5393	0.5906	0.6358	0.3331	0.7181	0.6680
	(0.0102)**	(0.0149)**	(0.0183)**	(0.0579)**	(0.1556)**	(0.4154)
$\ln INS_{ijgt}$	-0.1773	-0.2159	-0.1695	-0.0939	-0.2250	-0.2127
	(0.0034)**	(0.0052)**	(0.0070)**	(0.0196)**	(0.0486)**	(0.1673)
$\ln GDP_{jt}$	-0.0814	-0.0832	-0.0672	-0.0182	-0.0454	-0.0081
	(0.0055)**	(0.0060)**	(0.0123)**	(0.0191)	(0.0939)	(0.0824)
$\ln \frac{GDP_{jt}}{POP_{jt}}$	0.2495	0.1050	0.1289	0.0092	0.1039	0.0106
	(0.0052)**	(0.0064)**	(0.0107)**	(0.0125)	(0.1035)	(0.0439)
$\ln DIST_{ij}$	-0.0076	-0.1192	0.0251	-0.0455	-0.0873	-0.0949
	(0.0068)	(0.0026)**	(0.0184)	(0.0096)**	(0.1758)	(0.0677)
u.i.p-val ^{a}	0.000	0.000	0.000	0.000	0.006	0.190
C-D F-stat ^{b}	2451.0	926.7	603.2	74.7	4.9	1.0
N of igt	35051	31761	9939	8465	708	590
Obs.	371658	182103	94813	35909	4745	2244

Notes: Standard errors in parantheses. * significant at 5%; ** significant at 1%. All specifications include importer-product-year fixed effects α_{igt}. All specifications are estimated using 2SLS procedure implemented for STATA as `xtivreg2` by Schaffer (2005). ^{a}- p-value of the LM test for underidentification of all instrumented variables. ^{b}- Cragg and Donald (1993) F-statistics of test for weak identification of instrumented variables. The test for overidentification is not carried out because the instrumental variables are exactly identified.

to have a much stronger effect of bilateral trade barriers, which affects the self-selection of exporters and products, as is indeed observed: the magnitudes of the freight rate, transportation insurance, and distance coefficients are on average 1.5 times higher for the homogeneous goods than for the differentiated goods. Higher elasticity, on the other hand, means that the price absorbs a smaller fraction of the higher variable production cost. Thus, the variables that affect input prices, such GDP per capita (higher wages) and GDP (economies of scale and cheaper intermediates due to agglomeration) should have a weaker effect for the homogeneous goods. Indeed, the GDP per capita coefficient is on average two times lower for the homogeneous and reference goods than for the differentiated goods, where the absolute value of the GDP coefficient is 57% lower for the reference goods than for the differentiated goods and statistically insignificant for the homogeneous goods.

Table 3 shows the results for the sample split by both OECD membership and the degree of product differentiation. The MQC term coefficient is positive and significant only for the differentiated goods, negative and significant for the reference goods produced in the non-OECD countries, and statistically insignificant for the rest of the goods and countries. Therefore, the prediction of *Proposition* 1 is supported by the data in the differentiated goods samples only; it only holds true for the products for which we expect the geography to have an effect on quality.

Moreover, if the homogeneous goods sample is split into OECD and non-OECD sub-samples, almost none of the independent variables has a statistically significant effect on the export price, except for the freight rate and transportation insurance. Thus, the significance of the GDP per capita and distance coefficients in the unsplit sample is mainly due to the 'between' variation, which indicates significant differences in the price formation process of the homogeneous goods between developing and developed countries.

The $\ln DIST_{ij}$ row indicates that the difference in the strength of the distance effect between the OECD and non-OECD exporters, previously noted in the discussion of Table 1, stems mainly from the differentiated goods sample. Indeed, for differentiated goods, the distance variable coefficient is 16 times larger for the non-OECD countries than for the OECD countries.

Explanatory power of the model

In this sub-section, we relate the results of the estimation to the variation in the explanatory variables by calculating their effect on the export price. We concentrate on differentiated products for the OECD and non-OECD countries presented respectively in panels a and b of Table 4. The estimated coefficients for column 5 are taken from the first (for panel a) and second (for panel b) columns of Table 3. The tables report the 5^{th} percentile, the 95^{th} percentile, the standard deviation, and the mean for all dependent and independent variables as well as the beta-coefficients and the effect of the 5^{th}-to-95^{th} percentile change in each explanatory variable. All statistics are calculated only for the estimation sample, and all variables are mean-differenced with respect to the importer-product-year igt means to match the variation used in the estimation after controlling for α_{igt} fixed effects. The lower parts of each panel present the calculations intended to further demonstrate the effect of variation in the components of MQC. To understand the last two rows of each panel, note that the MQC index varies for two distinct reasons. The numerator of the MQC formula varies due to differences in the trade weighted quality preference parameter, while the denominator reflects variation in the trade weighted inverse of the distance. To separate the effect of these two parts, we calculate the effect of each holding the other at the sample mean.

The calculations in Table 4 suggest that variation in the MQC index explains anywhere from 4.2% to 7.6% of the variation in the export prices. Furthermore, the effect is stronger for the non-

Table 4: Explanatory power of the model.

Variable, Z[a]	5%	95%	σ	$\bar{Z}$	$\hat{\alpha}^a$	$\hat{\alpha}\sigma_Z$	$\hat{\alpha}(Z_{95\%} - Z_{5\%})$
	1	2	3	4	5	6	7
	a. Differentiated goods from OECD exporters						
$\ln p_{ijgt}$	8.02	11.46	1.06	9.67		1.060 [b]	3.45 [c]
$\ln f_{ijgt}$	5.36	8.97	1.11	7.07	0.573	0.634	2.07
$\ln INS_{ijgt}$	-6.58	-4.16	0.77	-5.26	-0.185	-0.142	-0.45
$\ln DIST_{ij}$	8.47	9.74	0.41	9.17	-0.754	-0.309	-0.96
$\ln\left(\frac{GDP_{jt}}{POP_{jt}}\right)$	8.64	10.63	0.58	9.96	0.162	0.095	0.32
$\ln GDP_{jt}$	25.26	29.80	1.30	27.37	-0.071	-0.092	-0.32
MQC_{jgt}	47.43	77.82	9.10	60.89	0.0048	0.044	0.15
$\bar{\delta}_{jgt}$	8.70	10.38	0.49	9.76	0.0048	0.015 [d]	0.05 [e]
$\overline{(1+a_{jgt})/\tau)}^{-1}_{jgt}$	4.83	7.88	0.91	6.25	0.0048	0.043 [f]	0.14 [g]
	b. Differentiated goods from non-OECD exporters						
$\ln p_{ijgt}$	7.40	10.64	0.99	8.97		0.994 [b]	3.24 [c]
$\ln f_{ijgt}$	4.77	8.30	1.06	6.41	0.573	0.610	2.02
$\ln INS_{ijgt}$	-6.37	-4.06	0.72	-5.17	-0.185	-0.134	-0.43
$\ln DIST_{ij}$	6.81	10.13	1.10	8.71	-0.754	-0.826	-2.51
$\ln\left(\frac{GDP_{jt}}{POP_{jt}}\right)$	6.38	9.81	0.97	7.89	0.162	0.157	0.56
$\ln GDP_{jt}$	23.48	28.09	1.34	25.84	-0.071	-0.095	-0.33
MQC_{jgt}	31.41	79.89	14.13	54.99	0.0054	0.076	0.26
$\bar{\delta}_{jgt}$	7.18	9.89	0.81	8.54	0.0054	0.028 [d]	0.09 [e]
$\overline{(1+a_{jgt})/\tau)}^{-1}_{jgt}$	3.43	8.56	1.44	6.45	0.0054	0.066 [f]	0.24 [g]

Notes:

[a] - all variables are mean-differenced with respect to igt means to match the variation used in the empirical specification. The summary statistics and values of $\hat{\alpha}$ in panesl a and b correspond respectively to the estimation samples of specifications 1 and 2 in Table 3.

[b] - calculated as $1 \times \sigma_{\ln p}$

[c] - calculated as $Z_{95\%} - Z_{5\%}$

[d] - calculated as $\hat{\alpha}\sigma_{\bar{\delta}} * \overline{(1+a)/\tau)}^{-1}_{jgt}$

[e] - calculated as $\hat{\alpha} \times (MQC^1_{95} - MQC^1_5)$, where MQC^1_{95} and MQC^1_5 are calculated respectively for the 95^{th} and 5^{th} percentile values of $\bar{\delta}_{jgt}$ and mean value of $\overline{(1+a)/\tau)}^{-1}_{jgt}$

[f] - calculated as $\hat{\alpha}\sigma_{\overline{(1+a)/\tau)}} * \bar{\bar{\delta}}$

[g] - calculated as $\hat{\alpha} \times (MQC^2_{95} - MQC^2_5)$, where MQC^2_{95} and MQC^2_5 are calculated respectively for the 95^{th} and 5^{th} percentile values of $\overline{(1+a)/\tau)}^{-1}_{jgt}$ and mean value of $\bar{\delta}_{jgt}$

OECD countries. These numbers are obtained by dividing the numbers in the MQC index row by the $\ln p_{ijgt}$ row of columns 6 and 7.[23] The relatively higher importance of geography for specialization in quality by the non-OECD countries can be attributed to the fact that OECD countries are closer to the quality frontier; in addition, technological factors may play a more significant role. On the other hand, the producers in developing countries are influenced by the demand characteristics of the destination markets.

Based on the effect of the 5^{th}-to-95^{th} change in the components of MQC, we can estimate the effect of the proximity to rich countries and of the multilateral Alchian-Allen effect. The exporters of differentiated goods that face a stronger demand for quality from rich trading partners systematically charge 5–9% higher prices for all destinations. The income of trading partners matters more for the non-OECD countries. At the same time, countries whose demand is especially distorted by the Alchian-Allen effect charge 14–24% higher prices. This effect is, again, stronger for the non-OECD countries. Overall, the Alchian-Allen effect seems to explain two to three times more variation in the exporter specific quality.

The tables also present a comparison of the amount of variation in the observed prices that can be explained by the exporter specific quality component versus the destination-specific adjustment. The bilateral variables explain more variation of the dependent variable than the exporter-specific variables. For the most part, transportation cost and distance seem to best explain the variation in the observed level of prices. This is not surprising, given that the 6-digit categories encompass a substantial amount of variation at a more disaggregated level; however, these are two different variations. The exporter-specific variation captures the effect of geography on all firms within an exporting country and represents variation in quality that is specific to an exporter and captures the comparative advantage in quality. Therefore, if a given country compensates for the geographic distortion to the domestic demand by producing 5% higher quality, this affects exports to *all* destinations.

Geography of Multilateral Quality Compensation

In this section, we rank countries according to their MQC, potential MQC measured by $\widehat{MQC}$, and their components $\bar{\delta}_{ijt}$ and $\overline{1 + a_{ijt})/\tau_{ijt}}^{-1}$. Our goal is to describe the relative geographic position of each country and to explore how different countries utilize their geographic starting conditions. We concentrate on the case of differentiated products, as the most appropriate. Calculations correspond to column 2 of Table 2. Figures 2 and 3 present the percentiles of the export-weighted country ranks in the components of MQC. We use weighted ranks because, for a given exporter, the ranks of

[23] The percentages should not be interpreted as the shares of variation explained by each variable because the contribution of each variable does not add up to 100% due to the correlation between the explanatory variables.

MQC and its components differ across the HS 6-digit products. The percentiles of trade weighted relative ranks are calculated as follows: for each exporter, we first calculate the rank for each component of MQC. The rank is then divided by the number of countries that export the same HS6, so that a country ranking 3^{rd} among 3 is not considered to be as important as an exporter that ranks 3^{rd} out of 20. As a result of such normalization, the highest rank always equals one. Next, we find the weighted average of the HS 6-digit product ranks for a given exporter j, where the weights are the shares of the HS 6-digit exports in j's total exports. This way, a higher rank in a more important HS 6-digit category receives a higher weight.

The percentiles of the resulting average ranks are reported in Figures 2 and 3. The vertical axis represents the trade-weighted relative rank of the inverse of $\overline{(1-a)/\tau_{jt}}$, which represents the strength of the multilateral Alchian-Allen effect. The higher the percentile, the more a country exports to destinations with a stronger Alchian-Allen quality upgrading effect on quality. The horizontal axis represents the trade-weighted relative rank of $\bar{\delta}$. A larger percentile means that the exporter sells more to destinations with stronger preferences for quality.

Figure 3 differs from Figure 2 in that it describes the components of the potential $\widehat{MQC}$, which is calculated based on the exogenous variation in GDPs and distances. In Figure 2, there is a strong tendency for the OECD countries to be located in the upper half by both components of MQC. In other words, the demand for exports from developed countries favors high quality. In Figure 3, OECD countries are everywhere except in the upper-left corner, with the exceptions of Israel and Finland. This suggests that countries facing a strong multilateral Alchian-Allen effect but that are far from the rich countries are not as successful in upgrading the quality of their exports.

Figure 4 represents another way to summarize relative exporter MQC. The figure combines the export-weighted relative rank of actual or realized MQC and potential $\widehat{MQC}$, which is calculated based on GDPs and distances.[24] The countries above the 45-degree line have, in essence, realized their quality potential because their export-weighted MQC is larger than their potential. Demand for exports from the countries above the 45-degree line favors high quality products more than what would be predicted by standard gravity forces, indicating that those countries have successfully compensated for their geographic position by upgrading the quality of their products. Particularly, the figure suggests that the OECD exporters of differentiated products are those countries that not only have a high potential for exporting high quality goods due to their geographic location but also have the technology to realize that potential. China is one example among the developing countries of a realized MQC exceeding the potential. Canada is an example of a country with a strong demand for high quality products mostly due to its integration with the US.

[24] The scattered nature of the plot should not be interpreted as evidence of a lack of correlation between the two measures. They are, in fact, strongly correlated.

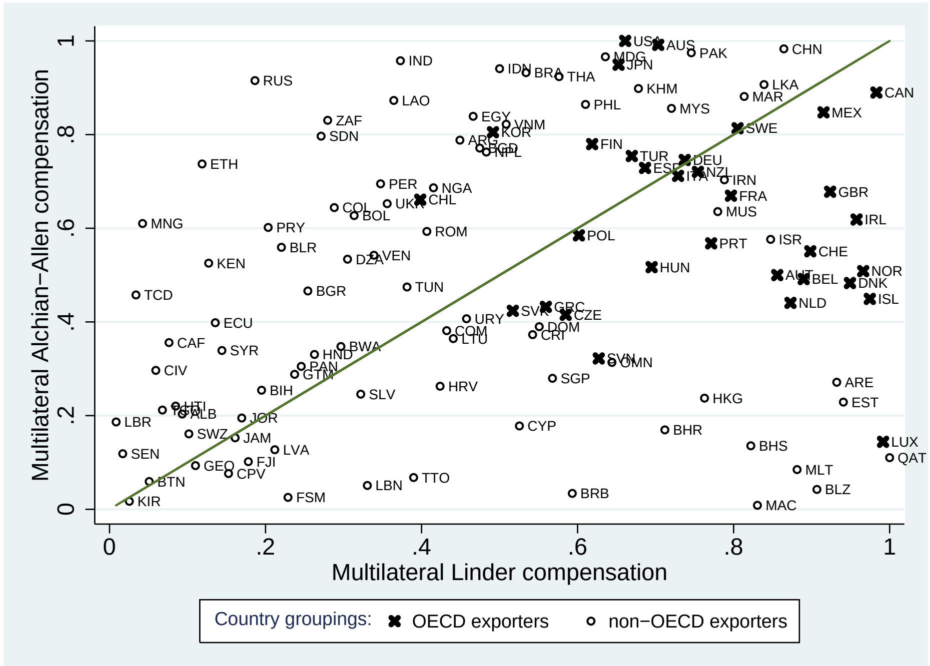

Figure 2: Export-weighted relative rank percentile of exporters by MQC components

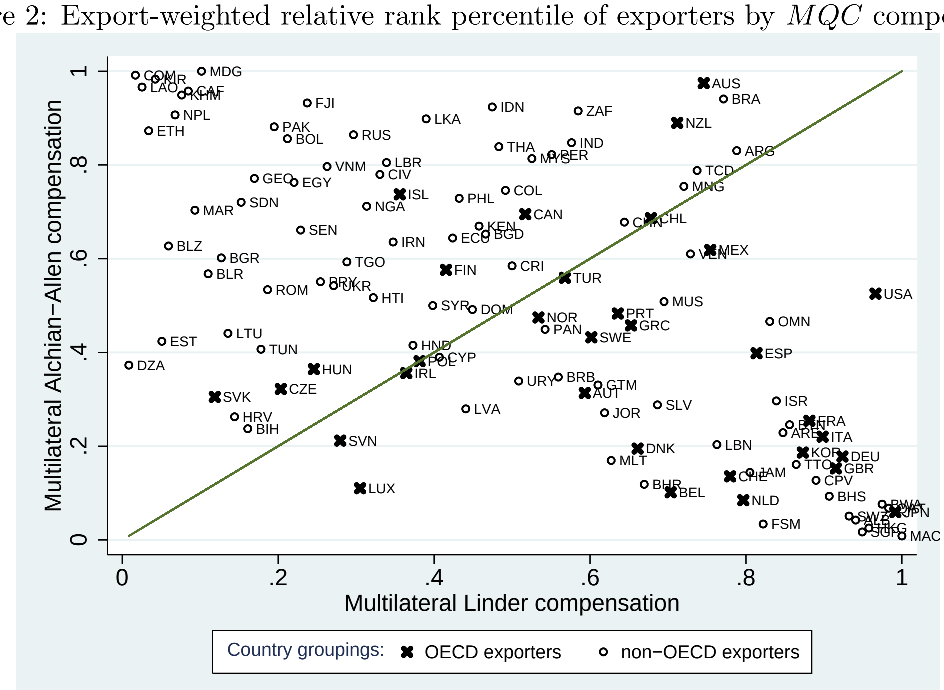

Figure 3: Export-weighted relative rank percentile of exporters by $\widehat{MQC}$ components

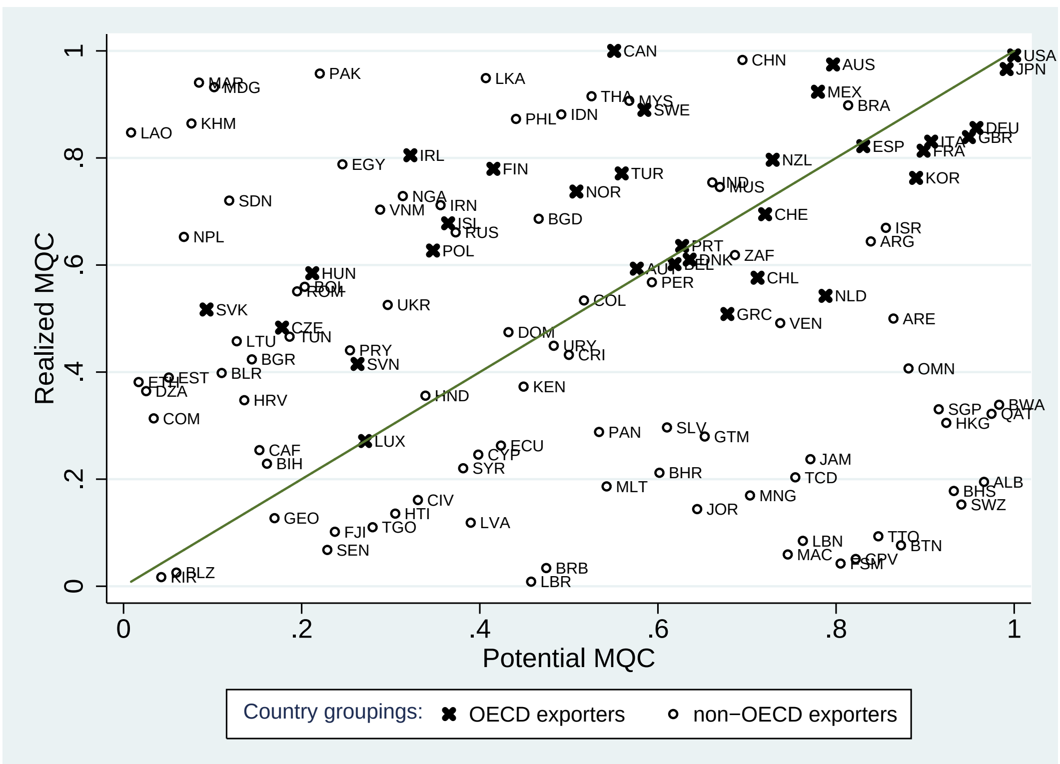

Figure 4: Export-weighted relative rank percentile of the potential versus realized MQC

4 Conclusions

We emphasize the role of multilateral geographic factors for the quality of a country's exports. In particular, proximity to richer export destinations increases quality due to a stronger preference for quality from these destinations, while a larger share of exports to more distant locations encourages the production of higher quality goods due to the smaller impact of the transportation cost on the delivered price for higher quality goods. The first channel follows from the generalized Linder's assumption, while the second one can be described as the Alchian-Allen supply-side effect. Both of these channels have appeared in the previous literature, but their main focus was on bilateral effects. We are the first to claim that all importers' characteristics affect the quality of the output and exports of any given country, and that the quality shipped to any destination depends on the demands from and transportation costs to all destinations.

The empirical results are consistent with our theoretical predictions. Importantly, our predictions obtain consistent empirical confirmation only for the set of goods that we expect to prove our predictions, namely, for differentiated goods. The quality choice based on geographic characteristics is not supported by the data for the homogeneous and reference goods. For the differentiated goods, the Multilateral Quality Compensation term explains 4.2% of the price variation for the OECD countries and 7.6% variation of prices for the non-OECD countries. This indicates that the quality choice of developing countries is more responsive to the geographic position and set of importers of a country of interest.

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Appendix: Second-order conditions for the single-quality firms.

Consider a producer of a single-quality variety v, with the profit function given by (6). Without loss of generality, let us assume that the demand for variety v is positive from $n>0$ countries. Then, the Hessian matrix of the profit maximization problem (6) is given by

$$H(\pi_v) = \begin{bmatrix} \frac{d^2\pi_v}{dP_{v1}^2} & 0 & 0 & \cdots & 0 & \frac{d^2\pi_v}{dP_{v1}d\lambda_v} \\ 0 & \frac{d^2\pi_v}{dP_{v2}^2} & 0 & \cdots & 0 & \frac{d^2\pi_v}{dP_{v2}d\lambda_v} \\ 0 & 0 & \frac{d^2\pi_v}{dP_{v3}^2} & \cdots & 0 & \frac{d^2\pi_v}{dP_{v3}d\lambda_v} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & \frac{d^2\pi_v}{dP_{vn}^2} & \frac{d^2\pi_v}{dP_{v1}d\lambda_v} \\ \frac{d^2\pi_v}{dP_{v1}d\lambda_v} & \frac{d^2\pi_v}{dP_{v2}d\lambda_v} & \frac{d^2\pi_v}{dP_{v3}d\lambda_v} & \cdots & \frac{d^2\pi_v}{dP_{vn}d\lambda_v} & \frac{d^2\pi_v}{d\lambda_2^2} \end{bmatrix} \tag{24}$$

where each of the first n diagonal elements is a second-order derivative of profit with respect to the delivered price charged to the i=1,2,3,...,n's destination. In order for the first-order critical values to be profit-maximizers, the Hessian evaluated at the potential solution has to be negative-definite. Now, for any $i \leq n$, the determinant of the upper left $i \times i$ matrix is equal to:

$$D_{i\times i} = \frac{\partial^2\pi_v}{\partial P_1^2} \times \frac{\partial^2\pi_v}{\partial P_2^2} \times \frac{\partial^2\pi_v}{\partial P_3^2} \times ... \times \frac{\partial^2\pi_v}{\partial P_i^2} \qquad \forall i \leq n, \tag{25}$$

where each multiplier is negative:

$$\left.\frac{\partial^2\pi_v}{\partial (P_{\text{-}vi})^2}\right|_{P_{vi}=P_{vi}*} = -X_{vi}\frac{\sigma w \tau_{vi} b_v}{P_{vi}^2} < 0 \qquad \forall i = 1, 2, ..., n. \tag{26}$$

Thus, the sign of the determinant (25) is negative if i is odd and positive if i is negative.

$$D_{i\times i} > 0 \quad \forall i = 2, 4, 6, ... \qquad\qquad D_{i\times i} < 0 \quad \forall i = 1, 3, 5, ... \tag{27}$$

Now, to prove that the $(n+1) \times (n+1)$ Hessian given by equation (24) is negative-definite it is sufficient to prove that the sign of the Hessian's determinant is negative if n is even and positive is

n is odd. Evaluated at critical values the determinant is equal to:[25]

$$|H(\pi_v)| = (-1)^n \tfrac{(\sigma-1)^2}{\sigma}$$
$$\times \sum_{l=1}^{n} X_{vl}^2 \left\{ \underbrace{\frac{\sigma-1}{\lambda_v}\delta_l \left(\frac{\delta_l}{\lambda_v} - 2\frac{1+a_l}{\beta\tau_{vl}}\right)}_{Z_1} + \underbrace{\frac{1}{\beta^2}\left[\sigma\left(\frac{1+a_l}{\tau_{vl}}\right)^2 - \frac{1+a_l}{\tau_{vl}} - \left(\frac{\overline{1+a}}{\tau_v}\right)^2 \frac{\delta_l}{\bar{\delta}^2}\right]}_{Z_2} \right\} \left(\prod_{i\neq l}^{n} X_{vi} \tfrac{\sigma w \tau_{vi} b_v}{P_{vi}^2}\right)$$

We start with finding conditions under which the term defined as Z_1 in the equation above is negative. From the first order conditions with respect to quality we know, that

$$\sum_{l=1}^{I} X_{vl} P_{vl} \left(\frac{\delta_l}{\lambda_v} - \frac{1+a_l}{\beta\tau_{-vl}}\right) = 0,$$

from which it follows that $\frac{\min(\delta_l)}{\lambda_v} \leq \frac{1+a_l}{\beta\tau_{-vl}}$ and $\frac{\max(\delta_l)}{\lambda_v} \geq \frac{1+a_l}{\beta\tau_{-vl}}$. Using this fact, the sufficient condition for Z_1 to be negative is given by

$$\max \delta_l < 2 \min \delta_l. \tag{28}$$

Next, a sufficient condition for the term defined as Z_2 to be non-positive is:

$$\frac{1+a_l}{\tau_{vl}} + \left(\frac{\overline{1+a}}{\tau_v}\right)^2 \frac{\delta_l}{\bar{\delta}^2} \geq \sigma \left(\frac{1+a_l}{\tau_{vl}}\right)^2. \tag{29}$$

The set of these parameter is non-empty, since we can always limit the preferences for quality parameter to be sufficiently small, so that $\frac{\delta_l}{\bar{\delta}^2}$ is sufficiently large for any given values of the elasticity and transportation cost parameters. Now, conditions (28) and (29) guarantee that the determinant of the Hessian given by the $(n+1) \times (n+1)$ matrix (24) is negative for $(n+1)$ being odd and positive for $(n+1)$ being even. Combined with the equation (27) this completes the proof that under conditions (28) and (29), the second order conditions are satisfied, and the critical values for equilibrium prices and quality (given by equations (7) and (11)) are profit-maximizers. If, on the other hand, the second order conditions are not satisfied, the optimal quality will be at one of the corner solutions (either $\underline{\lambda}$ or $\overline{\lambda}$) and the marginal changes of parameters explored in the Predictions subsection will not affect the optimal quality.

[25] Detailed derivation is provided in the Appendix for reviewers available at http://www.uwyo.edu/askiba.