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Quality Selection, Chinese Exports and Theories of Heterogeneous Firm Trade

by

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Abstract

Recent models of international trade have identified product quality as an important determinant of bilateral trade flows. Yet relatively little is understood about the relationship between the characteristics of the export market and the quality of products. In this paper we examine this link using Chinese data. We find evidence that product unit values vary with standard gravity variables in a different manner across sectors of the Chinese economy, and run contrary to earlier findings for the U.S. These results are not compatible with existing heterogeneous firm trade models such as Melitz (2003) model and its extension to include product quality by Baldwin and Harrigan (2007). To explain these differences we propose a heterogeneous firm trade model with quality differences and spatial price discrimination based on Melitz and Ottaviano (2007).

JEL classification: F1, F12

Keywords: product quality, heterogeneous firms, Chinese exports

Outline

Non-Technical Summary

Building on the now large literature modelling bilateral trade flows using gravity models, trade economists have begun to exploit newly available product level data to reveal how the components of aggregate trade flows, such as varieties, quantities and unit values, respond to various characteristics of trading partners. Some of the relationship found for unit values run counter to those found for aggregate trade flows and have been interpreted as suggesting that differences in product quality are important. Theoretical explanations consistent with this evidence have centred on the 'Alchien-Allen effect' and more recently the 'selection effects' that come from an extension of the heterogeneous firm trade model of international trade to allow for differences in product quality

In this paper we find that Chinese export prices are difficult to explain using heterogeneous firm models of international trade, including that with product-quality, and so we consider additional causes of geographic variation in unit values. We do this using the concept of 'spatial price discrimination' found in Melitz and Ottaviano (2006). In this new model export prices change across locations as producers respond to reflect the extent of competition in those markets. These selection and price discrimination effects work in opposite directions in the product quality model, leaving greater dispersion in the spatial variation of unit values.

Our empirical evidence uses data for over 7,000 Chinese products and 168 export destinations for the years 1997 to 2002. Grouping products according to their broad industry characterisation we find marked differences across industries. In our results none of the observations appear to match that predicted by the original heterogeneous firm model in which firms differ in their efficiency and just seven percent of the observations (3 industries) by its extension to account for product quality. All can be understood using our extended model. It follows from our results that we find no evidence for the common perception that Chinese exports compete internationally through low production costs.

1. Introduction

Recent empirical modelling by Schott (2004), Hummels and Skiba (2004), Hummels and Klenow (2005), Hallak (2006) and Baldwin and Harrigan (2007) has shown that the average unit value of internationally traded products vary with the per capita income, factor intensities, distance and the market size of trading partners. These empirical regularities have been interpreted as suggesting that differences in product quality are an important determinant of the pattern of international trade flows. Theoretical explanations consistent with this evidence have centred on the 'Alchien-Allen effect' and more recently the 'selection effects' that come from an extension of the heterogeneous firm trade model of international trade to allow for differences in product quality by Baldwin and Harrigan (2007) and Johnson (2007).

In this paper, motivated by the evidence that we present of a deviation between the spatial pattern of unit values for Chinese exports from that predicted by the heterogeneous firm model of international trade with product quality differences, we consider additional causes of geographic variation in unit values. We do this using the concept of 'spatial price discrimination' found in Melitz and Ottaviano (2006). In this new model (*f.o.b.*) export prices (mark-ups) change with the location (distance) and market size of export destinations via both the 'selection effect', and the 'price discrimination' effect, that occurs when export price mark-ups are endogenous. These selection and price discrimination effects work in opposite directions in the product quality model, leaving the relationship of export unit values with market size and distance ambiguous, but reinforce each other in a model where differences in firm efficiency, as in Melitz (2003), are key.

Our empirical evidence relies on data for over 7,000 Chinese products and 168 export destinations for the years 1997 to 2002. Grouping products according to their broad industry characterisation we find marked differences in the relationship between unit values and export market characteristics (distance and market size) across industries. For around two-thirds of the observations (12 industries) the coefficients on both market size and distance are found to be positive, in a quarter of the observations (4 industries) a positive coefficient is found on distance and negative coefficient found on market size, and in 7 per cent of the observation (3 industries) both variables have a negative relationship with average unit values. These results cannot be understood using the model of international trade where firms differ in their efficiency due to Melitz (2003), while the Baldwin-Harrigan (2007) extension of Melitz to account for differences in the quality of goods produced by firms can explain the results for less the 10 per cent of the observations found in the data.[1] The heterogeneous firm model with quality differences and spatial price discrimination is however, consistent with the Chinese evidence.

This empirical evidence we present is related to the work of Harrigan and Deng (2008) and Schott (2008). Using 2006 Chinese export data Harrigan and Deng (2008) also find that export unit values are increasing in distance from China to export markets. They offer a different theoretical explanation, based on an extension of Eaton and Kortum (2002) model to embed a Washington-apple like effect. The empirical approach of the paper is also closely related to Schott (2008). Using highly disaggregated US import data Schott (2008) shows that the mix of products exported by China to the US displays greater similarity to those of high income countries, but the price paid for these products (the unit value) is substantially lower. Under an assumption that differences in prices reflect differences in quality, Schott (2008) interprets this as consistent with a view that Chinese exports are of lower quality compared to those exported by high income countries.

The rest of this paper is organised as follows. In the next section we briefly review the existing evidence and theory on the link between average product unit value and the characteristics of exporters and importers as a guideline of our empirical analysis. Section 3 describes the data and methodology, while section 4 displays the results. The results we discovered for most export sectors with China seem to fall outside the empirical predictions from the original Melitz (2003) model even incorporating quality differences. In section 5 we instead propose a new version of the quality version of the heterogeneous firm trade model based on Melitz and Ottaviano (2007) with spatial price discrimination that is

[1] The predicted relationship for the Baldwin and Harrigan (2007) model holds for just three of the 19 industries we study (and in only one are both distance and market size significant), where these account for just 7.8 per cent of the total observations (6.9 per cent of HS8 codes).

consistent with the new empirical patterns we obtain for within China, and may also explain the differences between the results for China and those from other studies for the U.S.

2. Unit Values, Product Quality and Country Characteristics

Evidence

Building on the now large literature modelling bilateral trade flows using gravity models, trade economists have begun to exploit newly available product level data to reveal how the components of aggregate trade flows, such as varieties, quantities and unit values, respond to various characteristics of trading partners. In Table 1 we summarise the evidence for the three key empirical determinants of average product unit values from this literature, namely distance/transport costs, market size and per capita income.

Some of the relationships for unit values run counter to those found for aggregate trade flows from gravity models. For example, in contrast to the negative relation found between distance and aggregate trade flows, both Hummels and Skiba (2004), using 6 digit HS bilateral trade data for six importers and all exporters, and Baldwin and Harrigan (2007), using 10 digit HS export data for the US, find that average unit value increases with measures of transport costs/distance. The estimated elasticity on distance/ transport costs is also similar across these two studies. Hummels and Skiba (2004) find that the elasticity on freight rates is in the range 0.8-1.4 depending on estimation methods, while in Baldwin and Harrigan (2007) it was around 0.6. [2]

A second set of factors commonly examined in gravity equations is the size of the economy. Here the relationship is found to be sensitive to the measure used. Hummels and Klenow (2005) find the effects of the exporter's size on average unit values is fragile: the sign is negative when the size of the labour force is used as the proxy of the size of the economy,

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[2] Hummels and Skiba (2004) also find that, however, average unit value decreases in tariff , as a measure of ad-valorem trade costs.

but turns positive and marginally significant when GDP is used as the proxy. In contrast Baldwin and Harrigan (2007) find a more robust negative effect importer's economic size.

Using GDP per capita to measure size appears to generate a more robust relationship. Using HS 10 digit import data for the US Schott (2004) finds exporters' GDP per capita has positive effects on average unit value, with elasticity 0.13.[3] This is comparable to that by Hummels and Skiba (2004) of between 0.18-0.20. Hummels and Klenow (2005) also find a positive elasticity, but much smaller in size, which in turn is similar to that of Hallak (2006) for goods categories with different degrees of product differentiation. On the importer side, Hummels and Skiba (2004) report an elasticity with respect to importer per capita income in the range 0.53-0.62 when controlling for fixed exporter effects.

Theory

Despite this increasingly abundant empirical evidence on the spatial distribution of unit values trade theories that might explain them are in relatively short supply. The last column of Table 1 shows the relevant theoretical explanations for the corresponding evidence.

To explain the positive relationship with distance two alternative mechanisms have been formalised. The first, known as the 'Alchien-Allen effect',[4] argues that in the presence of quality differentiation within products, higher *per unit* transport cost lowers the relative price of high quality goods. This increases (decreases) the relative demand for high-quality (low-quality) goods. Two testable implications that follow from this argument are: (a) high-quality high-price goods will be exported while low–quality low-price goods will be kept for domestic consumption and (b) an increase in the *per unit* transport cost increases the within product average f.o.b. price, as market share reallocates towards high-price high-quality goods.

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[3] Schott (2004) also find that the average unit value increases with exporter's relative capital and skill abundance , which are all positively correlated with per capita income.

[4] This is also sometimes referred to as 'shipping the good apples out' or the 'Washington apple' argument.

Focusing on implication (b) Hummels and Skiba (2004) construct a simple theoretical model. They show how the form of the shipping cost function is crucial in describing the link between trade costs and average unit values. Unit value increase with *per unit* transport costs, such as freight rates, but decrease with *ad-valorem* costs, such as tariffs. This central argument is empirically confirmed in the same paper.

The 'Alchien-Allen effect' is however, not well suited to explaining the negative impact of importers' market size on average unit values found by Baldwin and Harrigan (2007). To understand the effects of *both* distance and market size, they incorporate quality differentiation into the new heterogeneous firm trade framework pioneered by Melitz (2003).[5] The innovation of their model is to assume firms differ in both marginal costs and quality, with a strictly positive quality-cost elasticity σ. High marginal costs produce higher quality products and also charges higher prices within the same product category. Due to the existence of the fixed exporting cost, firms self-select into the export market in terms of cost or quality. They show that when σ >1, quality increases disproportionally than costs. Thus high-cost-quality firms yield greater profits and become exporters, leaving the low-cost-quality firms to serve only the domestic market. Increasing trade costs (of an iceberg form in their model) or smaller (export) market size leads to stronger selection effects and increases the quality threshold required to export. Thus, average product quality increases with distance and decreases with market size of the export destination, as does the average f.o.b. price to that market. When σ <1, the mechanism is reversed: low cost-price-quality firms are selected into the export market, so that increasing distance and smaller market size leads to lower average product quality and f.o.b. price. Table 2 summarises these results.

To summarise, the existing literature has provided some empirical evidence that average product unit values respond to various characteristics of trading countries. From the theory the focus has been on the role of quality differentiation as a key element to explain these results, although there is some disagreement of the precise mechanism via which product

[5] Also see Roberts Johnson (2007).

quality matters. The next two section aims to contributes to both theoretical and empirical side of the link between unit value and importer's characteristics.

3. Data and Method

The data used for the empirical analysis are originally drawn from Customs General Administration of the People Republic of China for the years 1997-2002. These data record all export transactions, detailing information on the number of units traded (as well as the type of unit), the 'free on board' cost, the destination country and the HS8 industry (which we use here to describe products) as well as information on the ownership of the exporting firm (broken into 9 different types), and the type of trade undertaken (ordinary, processing etc. broken into 18 different types).

From the underlying data we aggregate firms' ownership according to whether they are state owned enterprises, are privately owned or have some degree of foreign ownership and split the type of trade according to whether it is ordinary trade, processing trade or other types.[6] We use only the part of the data that relates to ordinary trade, leaving a discussion of differences in the estimated relationships with those found for processing trade to Kneller and Yu (2008).

These data are of a similar type to that used by Harrigan and Deng (2008), previously by Swenson (2007), Chen and Swenson (2007) and detailed more fully in Feenstra, Deng, Ma and Yao (2004), but where they have further information on the location (city – these include in some cases city districts) from which the exports originate. The total sample size covers 7,724 HS8 industry codes for which we have non-zero unit values for at least one of the observed three years in our data (1997, 2000 and 2002) by country of destination. The total sample size is 437,271. As might be expected the number of observations rises over time, from 111,360 (1997) to 173,805 (2002). The results are robust to estimation by year or to pooling the data across years.

[6] We drop the residual observations measuring trade of other types following this classification.

Before moving on to the regression analysis we briefly detail some of the features of the data. A defining feature of our results is their variation across industries. We report in Table 3 the number of observations available at a broad industry level. As can be seen from the Table four sectors, Chemicals (HS codes 28-38), Textiles (HS codes 50-63), Base Metals (HS codes 72-83) and Machinery & Equipment (HS codes 84-85) account for 52 per cent of all observations.[7] In Figures 1a and 1b we report the distribution of the number of countries exported to within each HS8 product category for two industrial sectors (Chemicals and Machinery & Equipment). As can be seen from the figure the distribution is in both cases highly skewed, most products are exported to just a few countries.

There are some differences between the two sectors however, while the model number of countries is one in both sectors, the median value is 18 in Chemicals and 27 in Machinery and Equipment. Or as alternative evidence on the skew in the distribution 35 per cent of products are exported to less than 10 countries in the Chemicals sector, whereas in the Machinery and Equipment sector it is 26 per cent.

The variable of interest in the study is the unit value price of exports for each HS8 product from China to each of the 168 countries listed in the sample and for which we have complete data on the control variables.[8] This variable captures the *f.o.b.* export price averaged across all firms that export a given product to a given destination in the theoretical model. Unit value of product p to country j, u_{pj}, are calculated by dividing the f.o.b. export value, V_{pj}, by export quantity, Q_{pj},

$$u_{pj} = V_{pj} / Q_{pj}.$$

In the more formal analysis we regress these unit values in period t against a measure of distance from China to country j, dist_{jt}, as well as a measure of market size, GDP_{jt}, wealth per capita, GDPpc_{jt}, a Border dummy, BORDER, a set of time dummies, TD, and product

[7] In Table A1 in the appendix we report the number of observations per country. As might be expected countries that are large (measured by GDP) and are geographically relatively close to China have a larger number of observations.
[8] As discussed in Schott (2006) unit values are likely to include measurement error as a result of the misclassification of products. For that reason he, as do we, focus on heterogeneity in prices within product ranges. It should also be noted that Schott (2006) as well as Bernard et al. (2007) and Baldwin and Harrigan (2007) use HS 10 digit data.

fixed effects. The product (HS8 industry) fixed effects control for differences in average unit value across products as well as any differences in units (kilograms, tonnes etc.).[9] The regression equation is of the form:

$$\log(u_{pjt}) = a_p + \beta_1 \log(dist_j) + \beta_2 \log(GDP_{jt}) + \beta_3 \log(GDPpc_{jt}) + \beta_4 BORDER_j + \beta_5 TD + \varepsilon_{pjt}$$

Data on GDP and GDP per capita are from the World Bank, while the data on distance is a measure of weighted distance from CEPii and used previously by Head and Mayer (2002). The average distance from China is 7,795 kilometres. The closest country is recorded as South Korea (1,123km) and the furthest is Argentina (19,110km).

Using this data we are also able to replicate the type of evidence on unit values presented in Schott (2006) with the Chinese data. In Figures 2a and 2b we consider a scatter plot of unit values against GDP per capita for two HS8 products, Absorbent gauze or muslin bandages (HS8:30059010) and Motorcycles with reciprocating internal combustion piston engine, 50-250cc (87112000). These codes are chosen on the basis that these are products are exported to many countries (135 and 131 countries respectively). Consistent with the evidence for the US, there would appear in both of these graphs a generally positive relationship between average unit values per destination and GDP per capita. For example, the price per kilogram paid for absorbent gauze or muslin bandages is \$0.51 in Brazil and \$3.33 in the US and as high as \$9.38 in Austria. Similarly there are large differences in the unit price per motorcycle. The unit price is \$170 in Vietnam, \$417 in Malaysia, \$639 in the US and \$1,995 in New Zealand.

4. Empirical Results

In Table 4 we report the results from the regression on of unit-prices by broad industrial sector, where we group the results according to the combination of signs on the distance

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[9] The data have been checked that the units of measurement are the same within every hs8 category.

and market size variables.[10] Perhaps most obvious from the Table is the lack of support for the theoretical predictions set out in Table 2. Firstly, in no industries do we find the negative-positive (distance/market size) combination predicted by the 'efficiency sorting' version of the model. This somewhat surprising as this follows from the original Melitz model and would perhaps represent the standard view of Chinese comparative advantage. Secondly, the positive-negative combination suggested by the 'quality sorting' version of Melitz-Baldwin-Harrigan and the empirical evidence for the US are replicated in Chinese exports for only one industry (Pearls, precious metals and jewellery) out of 19 industries, although there are another three sectors with the expected combination of signs and at least one insignificant coefficient. These four sectors only account to 7.8 per cent of the total observations (6.9 per cent of HS8 codes), while the jewellery sector 0.3 per cent (2.3 per cent of HS8 codes).

The most common combination is for the estimated coefficients on both distance and market size to be positive. For twelve of out 19 industries we find this combination of coefficients and both coefficients are significant in 9 industries, including some crucial export sectors for China such as textile, wood products, base metals and chemicals. The products with this positive relationship with distance and market size represent 64.7 per cent of the total number of observations, or 67.4 per cent of available product codes. There is also evidence from the previous literature that these results are not unique to Chinese exports. Interestingly this result matches those found for Belgian and French exports in Mayer and Ottoviano (2007). Finally, there are three industries for which we find that average unit values decline with distance and market size. These industries account for a nontrivial proportion of the sample: 27.5 per cent of all observations and 25.7 per cent of products. Both of these two combinations fall outside the predictions of Table 2. Specifically, the positive-positive combination of coefficients estimates, which is found in the majority of Chinese export sectors, is inconsistent with all the existing versions of the

[10] The regressions include other standard gravity variables such as GDP per capita . For expositional purpose we do not report them in the table 4. Consistent with previous studies , the coefficients for GDP per capita are positive for most of the regressions. Details of these results are available from the author upon request, also see Kneller and Yu (2008).

heterogeneous firm trade models including the Melitz (2003) Baldwin and Harrigan (2007) and Melitz and Ottaviano (2007). [11]

5. A Model with Quality sorting and Spatial Price Discrimination

The Baldwin and Harrigan (2007) paper demonstrates that the sign of the coefficients of distance and market size will be positive and negative respectively, under quality sorting when the elasticity of quality is greater than one, but reversed under efficiency sorting when the quality elasticity is less than one. Our results for China suggest that neither version of these models may apply universally. Specifically, we find variation across industries, and for the majority of industries, a combination of signs that do not provide strong support for either version of the model.

In the rest of this section we consider the possibility of an additional mechanism through which spatial variation in unit values might be generated. Specifically we modify the Melitz-Ottaviano(2007) model by allowing asymmetric varieties and a positive link between the cost and the qualities of varieties as introduced by Baldwin and Harrigan (2007) and Johnson (2007). One important feature of this model is that, unlike the CES case where an exporter will charge identical f.o.b. prices across markets, the optimal firm level f.o.b. export price will vary across export destinations with different distances and market size. We label this effect 'spatial price discrimination'.

With spatial price discrimination, distance and market sizes affects average export unit value because of the compositional changes of firms entering the export markets, but in addition because of their effect on the f.o.b. price mark-ups for individual firms. We show that by adding these new dimensions, the heterogeneous firm trade model yield combinations of the coefficients for distance and market size in a regression of average unit-values that might explain our Chinese evidence, but also lead to different implications for the pattern of quality sorting and the effects of distance and market size on export quality relative to Baldwin and Harrigan (2007).

[11] Baldwin and Harrigan (2007) demonstrate a negative-negative sign combination can be derived from the original Melitz and Ottaviano (2007) model.

The Model

We begin by considering a closed economy and then extend to the open economy version. Consider an economy with *L* identical consumers, each supplying one unit of labour as the only factor of production. We follow Melitz and Ottaviano (2007) and assume that preferences across differentiated varieties within a sector are characterised by a quasi-linear utility with a quadratic sub-utility. We modify the demand system to accommodate *asymmetric* varieties as follows:

$$u = q_0 + \alpha \int_{i\in\Omega} (z_i q_i) di - \frac{\gamma}{2} \int_{i\in\Omega} (z_i q_i)^2 di - \frac{\eta}{2} \left(\int_{i\in\Omega} (z_i q_i) di \right)^2$$

Where u is the utility of an individual representative consumer, q_0, z_i, q_i and M are respectively, consumption by the representative consumer of the homogeneous good, quality of variety *i* and quantity of variety *i* in the differentiated sector and the number of varieties available in that sector. Note that z_i indexes the quality of a variety and consumers enjoy greater utility from a variety with higher value of z_i. Parameter γ indexes the degree of product differentiation across varieties, the larger γ the more differentiated are varieties. Parameters α and η index the degree of substitution between the numeraire good and differentiated goods: the consumer's demand is biased toward the differentiated good relative to the numeraire good the higher is α or the lower is η. α, η and γ are assumed positive and identical across countries. These preferences lead to the following inverse demand function:

[1] $$\frac{p_i}{z_i} = \alpha - \gamma \cdot z_i q_i - \eta Q ,$$

Where $Q = \int_{i\in\Omega} (z_i q_i) di$ is the aggregate (quality adjusted) consumption. Let $\Omega^* \subset \Omega$ be the subset of varieties consumed ($q_i > 0$). The linear demand system for each individual variety is:

[2] $$q_i = \frac{L}{z_i \gamma} \left(\hat{P} - \frac{p_i}{z_i} \right), \qquad i \in \Omega^*$$

where $\hat{P} \equiv \dfrac{\eta M\overline{P} + \alpha\gamma}{\eta M + \gamma}$ is the quality adjusted price-ceiling common for all varieties, above which the demand for an individual variety will be zero. $\overline{P} = \int_{i\in\Omega^*}\left(\dfrac{p_i}{z_i}\right)di \Big/ M$ represents the average quality-adjusted price of the differentiated varieties, where *M* is the number of varieties being consumed.

On the production side of the model, labor is the only factor of production. Production of the numeraire good exhibit constant return to scale at unit cost under competitive market. This assumption leads to unit wage. There is a continuum of firms pay a sunk fixed entry cost f_e to enter the market, and then randomly draw their constant marginal cost c_i from an exogenous common distribution $G(c)$ with support [$0, c_M$]. Since firms' operating profits are $\pi_i = (p_i - c_i)q_i$, the first order condition of profit maximisation yields the following optimal quantity:

[3] $$q_i = \frac{L}{\gamma}\frac{[p_i - c_i]}{z_i^{\;2}}$$

Substituting [3] into [2] we derive the optimal pricing rule given cost *c* (we omit the firm subscript *i* hereafter):

[4] $$p(c,z) = \left(z \cdot \hat{P} + c\right)\Big/2$$

This yields the optimal quantity of production, revenue and profit.

[5] $$q(z,c) = \frac{L}{2\gamma \cdot z}\left(\hat{P} - \frac{c}{z}\right), \qquad \frac{c}{z} < \hat{P}$$

[6] $$r(z,c) = \frac{L}{4\gamma}\left[\hat{P}^2 - \left(\frac{c}{z}\right)^2\right], \qquad \frac{c}{z} < \hat{P}$$

[7] $$\pi(z,c) = \frac{L}{\gamma}\left(\frac{p-c}{z}\right)^2 = \frac{L}{4\gamma}\left(\hat{P} - \frac{c}{z}\right)^2, \qquad \frac{c}{z} < \hat{P}$$

where $\frac{c}{z} < \hat{P}$ is the 'survival condition'. Only varieties with quality adjusted costs lower than the price ceiling will face positive demand ($q(z,c) > 0$). Firms producing higher quality products for a given cost will charge higher prices and earn greater revenue and profits, although it does not necessarily follow there will also enjoy higher demand[12].

Following Baldwin and Harrigan (2007) and Johnson (2007), we assume that z is positively correlated to c. Higher cost firms produce higher quality, $z = c^{\sigma}$, $\sigma \in [0, \infty)$. Hence, equation [4]-[7] can be rewritten as

[8] $$p(c) = \left(c^{\sigma} \cdot \hat{P} + c\right)/2, \qquad c^{1-\sigma} < \hat{P}$$

[9] $$q(c) = \frac{L}{2\gamma \cdot c^{\sigma}}\left(\hat{P} - c^{1-\sigma}\right), \qquad c^{1-\sigma} < \hat{P}$$

[10] $$r(c) = \frac{L}{4\gamma}\left[\hat{P}^2 - c^{2(1-\sigma)}\right], \qquad c^{1-\sigma} < \hat{P}$$

[11] $$\pi(c) = \frac{L}{4\gamma}\left(\hat{P} - c^{1-\sigma}\right)^2, \qquad c^{1-\sigma} < \hat{P}$$

where $c^{1-\sigma} < \hat{P}$ is the 'survival condition' that must be satisfied in all the above equations to yield positive demand for each variety. From [10] and [11] it is straightforward to show that profit and revenue are increasing (decreasing) in marginal cost when the quality elasticity is greater(less) than one:

[12a] $$r'(c) > 0, \quad \pi'(c) > 0, \quad \forall c > c_D \equiv \hat{P}^{\frac{1}{1-\sigma}}, \text{ if } \quad \sigma > 1$$

[12b] $$r'(c) < 0, \quad \pi'(c) < 0, \quad \forall c < c_D \equiv \hat{P}^{\frac{1}{1-\sigma}}, \text{ if } \quad \sigma < 1$$

Where c_D is the cost cut-off under (above) which firms can survive and earn positive profits when the quality elasticity is low (high). We close the model by assuming free entry

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[12] From [5], $\frac{\partial q}{\partial z} = \frac{L}{2\gamma z^2}\left(-\hat{P} + \frac{2c}{z}\right)$, implying an inverse U shape relation between demand and quality: $q(c,z)$ is maximised when $z = 2c/\hat{P}$.

into the market. The equilibrium is therefore characterised by the zero net expected profit condition:

$$[13a]\quad \Pi \equiv \int_{c_D}^{c_M} \pi(c)dG(c) + \int_0^{c_D} 0dG(c) = \frac{L}{4\gamma}\int_{\hat{P}^{\frac{1}{1-\sigma}}}^{c_M} \left[\hat{P} - c^{1-\sigma}\right]^2 dG(c) = f_e \quad , \quad \text{if} \quad \sigma > 1$$

$$[13b]\quad \Pi \equiv \int_0^{c_D} \pi(c)dG(c) + \int_0^{c_D} 0dG(c) = \frac{L}{4\gamma}\int_0^{\hat{P}^{\frac{1}{1-\sigma}}} \left[\hat{P} - c^{1-\sigma}\right]^2 dG(c) = f_e, \quad \text{if } \sigma < 1$$

It is straightforward to show that $\frac{\partial \Pi}{\partial \hat{P}} > 0$ and $\frac{\partial \Pi}{\partial L} > 0$ for any σ, so we obtain $\partial \hat{P} / \partial L < 0$. In words, larger markets have lower price ceilings in equilibrium. Note that this result is identical to the original Melitz and Ottaviano (2007) model in the absence of quality differences, where they show that larger markets lead to a lower price ceiling and price mark-up. The difference however, is that here the effects of market size on the survival cost cut off ($c_D \equiv \hat{P}^{\frac{1}{1-\sigma}}$) is ambiguous, depending on the quality elasticity, $\frac{\partial c_D}{\partial L} > (<) 0$, $\sigma > (<) 1$.[13] Larger market leads to increased cost cut-offs, if and only if, the elasticity of quality to cost is greater than one. However, independent of the value of σ, larger market size always leads to stronger selection into the industry i.e. lower survival rate [14].

Spatial Price discrimination and export selection

Now we turn to the open economy version of the model to investigate the joint effects of distance and market size on the average unit value of Chinese exports. Consider a world comprising of a home country China, and *J* foreign countries indexed by *j*. All countries share common technology, characterised by the distribution of firm level marginal costs $G(c)$ and other parameters, but differ in their market sizes and distance to China.

[13] Note that $\frac{\partial c_D}{\partial L} = \hat{P}^{\frac{\sigma}{1-\sigma}} \left(\frac{1}{1-\sigma}\right) \frac{\partial \hat{P}}{\partial L}$. Since $\frac{\partial \hat{P}}{\partial L}$<0, the sign of $\frac{\partial c_D}{\partial L}$ depends on σ.

[14] Note that firms survive for $c > (<) c_D$ when $\sigma > (<) 1$. This indicates that when $\sigma > 1$ firm survival rate $1 - G(c_D)$ is decreasing in c_D; and when $\sigma < 1$ firm survival rate $G(c_D)$ is increasing in c_D.

Transportation cost takes the form of a standard melting-ice-berg cost $t^j > 1$ that is increasing in distance.

A firm with cost *c* from China may decide to serve market *j* by producing output $q_X^j(c)$ at a delivered (c.i.f.) price $p_x^j(c)$. A potential Chinese exporters profit from serving a given foreign market is $\pi_X^j(c) = \left[p_X^j(c) - t^j c\right] q_X^j(c)$. Analogous to the case in the closed economy in [2]-[9], export demand is $q_X^j = \frac{L^j}{c^\sigma \gamma}\left(\hat{P}^j - \frac{p_X^j}{c^\sigma}\right)$ and the profit maximising export output must satisfy $q_X^j = \frac{L^j}{\gamma}\frac{\left[p_X^j - t^j c\right]}{c^{2\sigma}}$, which yields the following optimal export price and output:

[14a] $$p_X^j = \frac{1}{2}\left(\hat{P}^j c^\sigma + c \cdot t^j\right), \qquad p_{Xf}{}^j = \frac{p_X{}^j}{t^j} = \frac{1}{2}\left(\frac{\hat{P}^j c^\sigma}{t^j} + c\right)$$

[14b] $$q_X^j = \frac{L_j}{\gamma z}\left(\hat{P}_j - \frac{p_X^j}{z}\right) = \frac{L^j}{2\gamma \cdot c^\sigma}\left(\hat{P}^j - c^{1-\sigma} t^j\right)$$

Where $p_{Xf}{}^j$ denotes the corresponding optimal f.o.b. price. Most importantly [14a] reveals the existence of 'spatial price discrimination'. Unlike the CES case, where an exporter charges identical f.o.b. prices and mark-ups across markets, now both f.o.b. price $p_{Xf}^j(c)$ and its markup $\left(p_{Xf}{}^j / c\right)$ vary with t^j. Firms charge different f.o.b. prices and mark-ups across export destinations depending on their distance from China. Other things equal, a firm will charge a *lower* f.o.b price for a more distant market, despite the higher c.i.f. price. The intuition behind this result is that under the sub-quadratic utility assumption the elasticity of demand varies along a firm's residual demand curve, and the elasticity is greater for higher trade costs.[15]

[15] This is because consumer demand will be more "sensitive" to changes in price when the c.i.f. price is higher, the later is increasing in trade costs.

In addition, ${p_{Xf}}^{j}$ also depends on the "competitiveness of the market" reflected in $\hat{P}^{j}$. Intuitively, when competition in the market is "tougher", the price ceiling $\hat{P}^{j}$ becomes lower, which forces exporters to charge lower f.o.b. prices. Reasoning analogous to the case in the closed economy, and unlike the original Melitz model under CES preferences, market size affects the f.o.b. prices of individual exporters via their effects on $\hat{P}^{j}$. Since $\hat{P}^{j}$ decreases in L^{j} since larger markets lead to tougher competition and lower industrial price ceilings, $p_{Xf}^{j}(c)$ decreases in L^{j}, exporters charges lower f.o.b. prices in larger markets, other things equal. The intuition is that when selling to a larger market with tougher competition, a firm's residual demand curve shifts inwards leading to a higher price elasticity and thus a lower optimal price.

Finally, [14b] implies that the survival condition written in terms of generating a positive demand in market $j\ \left(q_{X}^{j} > 0\right)$ is

[15] $$c^{1-\sigma} < \hat{P}^{j}\left(t^{j}\right)^{-1}$$

This implies that there exists the following export cost cut off that separates exporters and non-exporters:

[16] $$c_{X}^{j} = \left(t^{j}\right)^{\frac{1}{\sigma-1}} \hat{P}_{j}^{\frac{1}{1-\sigma}}$$

For firms satisfying condition [15] , their (positive) export profits will be given by,

(17) $$\pi_{X}^{j}(c) = \frac{L^{j}}{2\gamma}\left(\hat{P}^{j} - c^{1-\sigma}t^{j}\right)^{2}$$

This implies $\pi_{X}^{j}{}'(c) > 0$ for $c > c_{X}$ when $\sigma > 1$, and $\pi_{X}^{j}{}'(c) < 0$ for $c < c_{X}$ when $\sigma < 1$. In words, when the quality elasticity is high export profits increase in cost and quality, so firms with costs above the export cost cut off earn positive export profits. High quality high price(cost) firms self-select into the export market and we have the pattern of 'quality sorting' by exporters. The opposite holds for low values of the quality elasticity parameter. Then firms will be sorted in terms of having lower cost into the export market and we have the pattern of 'efficiency sorting'. Next we generate the predictions of the effects of market size and distance on average unit value of exports from our model corresponding to the above two sorting patterns, and reveal how they differ from the existing heterogeneous firm trade models.

Quality Sorting

Firstly we look at the case of quality sorting. When $\sigma > 1$, the cost range of exporters to market *j* is $\left[c_X^j, c_M\right]$, thus the average f.o.b. export price to market *j* from China is:

$$[18] \qquad \overline{p}_{Xf}^j = \frac{\int_{c_X^j}^{c_M} p_{Xf}{}^j(c)dG(c)}{1-G(c_X^j)} = \frac{\int_{c_X^j}^{c_M} \left(c^\sigma \hat{P}^j t^{j-1} + c\right)dG(c)}{2\left[1-G(c_X^j)\right]}$$

How does $\overline{p}_{Xf}^j$ responds to distance (t^j) and market size (L^j)? t^j and L^j affect $\overline{p}_{Xf}^j$ via two mechanisms. The first is the 'selection effect'. Variations in t^j and L^j lead to changes in the export cost cut off c_X^j and therefore the compositional changes in Chinese exporters to market *j*. As a result, average unit value of Chinese exporters in *j* will also change. It can be shown from (18) that $\partial \overline{p}_{Xf}^j \big/ \partial c_X^j > 0$. Further, since as per (16) $\partial c_X^j \big/ \partial t^j > 0$, $\partial c_X^j \big/ \partial \hat{P}^j < 0$ when $\sigma > 1$, and recall that $\partial \hat{P}^j \big/ \partial L^j < 0$, we conclude that *both* market size (L^j) and distance (t^j) tend to have *positive* effects on average export unit value ($\overline{p}_{Xf}^j$) via the selection effect. The intuition behind this result is that, when the quality elasticity is greater than one, firms are sorted into the export market in terms of high quality high cost, with c_X^j being the *minimum* marginal cost level required for exporting. A larger market size results in tougher competition and lower price mark-ups in the export market such that selection into the export market is stronger. As a result, more low-cost low-quality firms are forced to leave the export market, which increases the average cost and quality of remaining exporters. Average f.o.b. export price and export quality therefore increases. Reasoning analogously, higher transport costs increases trade barriers, leading to stronger selection and to increased average f.o.b. export price and quality.

However, a second mechanism, namely the 'price discrimination effect', is also at work. As discussed before as per [14a], $p_{xf}{}^{j}(c)$ decreases in both t^{j} and L^{j} as the optimal f.o.b. export price is now endogenous to the characteristics of the export markets. Hence, the 'selection effects' and 'price discrimination effects' pull in opposite directions leaving the net effect ambiguous.

Efficiency sorting

Next we consider the case when the quality elasticity is lower than one. In this version exporters are sorted by having lower costs, therefore the average f.o.b. export price is

$$[19] \quad \overline{p}_{Xf}^{j} = \frac{\int_0^{c_X^j} p_{Xf}{}^{j} dG(c)}{G(c_X^j)} = \frac{\int_0^{c_X^j} \left(c^{\sigma} P^{j} t^{j-1} + c\right) dG(c)}{2G(c_X^j)}$$

Again we can decompose the effects of distance and market size into the selection effect and the price discrimination effect. From [16] $\partial c_X^j / \partial t^j < 0$ and $\partial c_X^j / \partial \hat{P}^j > 0$ when $\sigma < 1$, and from [19] $\overline{p}_{Xf}^{j}$ is increasing in c_X^j, therefore $\overline{p}_{Xf}^{j}$ decreases in t^j and L^j (again, using the result that $\partial \hat{P}^j / \partial L^j < 0$). Hence the selection effect is negative for both market size and distance. Furthermore, since the price discrimination effects are also negative, the total effects of both market size and distance on average export quality and unit value are *unambiguously* negative.

We summarise the above results in Table 5. Note that Table 5 provides very different predictions compared to those from Baldwin-Harrigan (2007) as summarised in Table 2. Our model predicts that under the quality sorting all four possible combinations are possible, depending on whether the selection or price discrimination effect dominates. In contrast under efficiency sorting the both signs are always negative.

Reassessing the evidence from the new model

As a final exercise we return to empirical evidence presented in Section 4, a summary of which can be found in Table 6. Using the model with selection and price discrimination the ‘double positive’ coefficients on distance and market size found for the majority of the Chinese exports and for France and Belgium exports by Mayer and Ottaviano (2007) requires that the quality selection dominates, and that average export quality increases in both distance and market size. Most importantly, and in contrast to the product quality model of Baldwin-Harrigan (2007), which is incompatible with the positive coefficient on distance that we find, the extension of Melitz and Ottaviano (2007) to account for product quality predicts that increasing market size could actually lead to stronger quality selection effect and therefore higher unit values. The positive coefficient on market size in this model is therefore consistent with a positive coefficient on distance, but also categorically indicates that products are sorted according to their quality by exporters.

As shown in the second to third rows of the table, by incorporating spatial price discrimination it is possible to generate a the unified model that can account for other combinations of the coefficient signs in a unit value regression. According this model the positive-negative market size-distance combination found to be significant for the US by Baldwin and Harrigan (2007) would, as in their model, be consistent with an interpretation that product quality characteristics are important in determining patterns of trade, but because the (negative) price discrimination effects dominate. Finally, the double negative combination on distance and market size found for two Chinese export sectors, including one of the largest export sectors (Machinery and Equipment), is consistent with both efficiency sorting and quality sorting hypothesis as a consequence of price discrimination in our model. This can be viewed as a consistent with Melitz and Ottaviano (2007), but should not necessarily imply efficiency sorting. It is possible that Chinese exporters in the Machinery and Equipment sector are also sorted by quality, but that price discrimination effect dominates the selection effect. Given the importance of the Machinery and Equipment sector to Chinese trade and inward investment flows discriminating between these two hypothesis may be an interesting future exercise. Finally, perhaps somewhat surprisingly, the predictions for unit values from the model of Melitz (2003) are difficult to match with our evidence for Chinese exports. This again stresses the importance of quality differences as a key dimension in our understanding of the relation between export unit value and characteristics of the destination markets.

6. Concluding Remarks

In this paper we found new features of the average unit value of Chinese exports compared to existing evidence that could not be fully captured by existing models of heterogeneous firms and international trade. In particular, for the majority of Chinese exports we found unit values increase with both distance and market size, while other combinations of signs were also found to be significant in a few sectors. These findings are difficult to interpret using the Melitz (2003) and its extension by Baldwin Harrigan (2007) to incorporate product quality differences across firms.

To reconcile the gap between our new evidence and the existing theory, we proposed an extension of the Melitz and Ottaviano (2007) model allowing for quality differences suggested by Baldwin and Harrigan (2007). A distinguishing feature of this new model is that distance and market size affect unit value through both price discrimination and quality selection effects. Further, in contrast to the common perception that Chinese exports compete internationally through low production costs, our findings imply that in the majority of manufacturing sectors Chinese firms are sorted by the quality of the goods they offer into export markets.

Figure 1a Distribution of the number of export destinations : Chemical sector

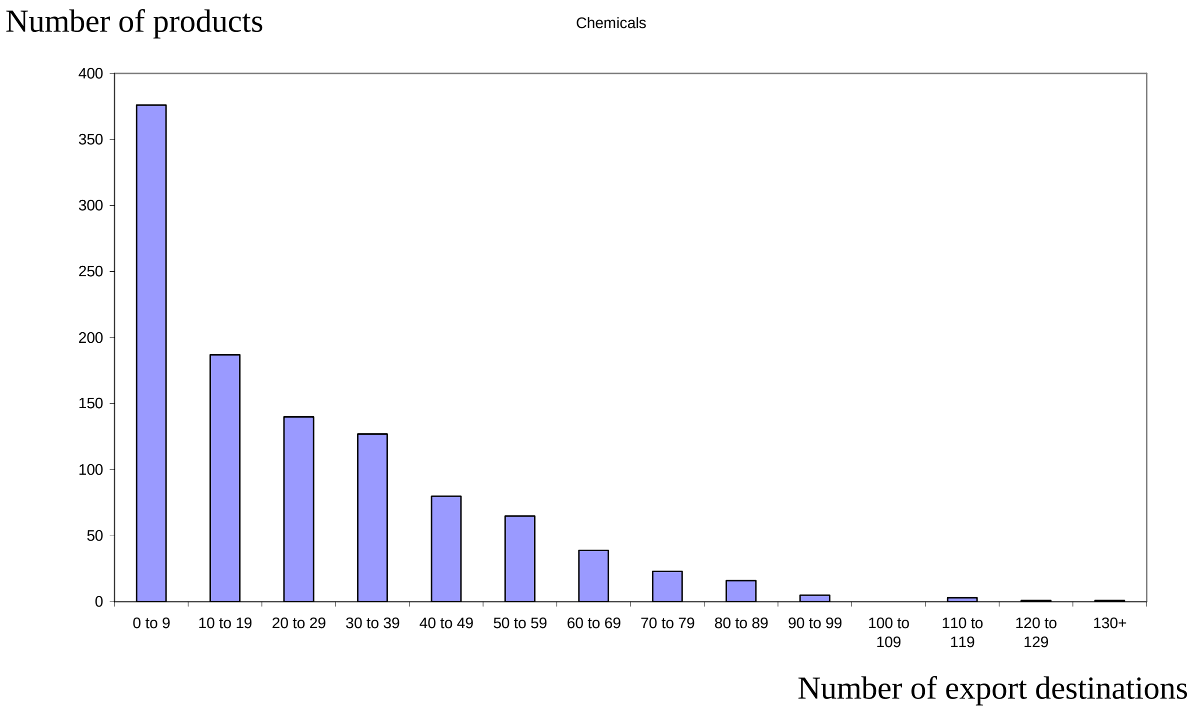

Figure 1b : Distribution of the number of export destination countries : Machinery and Equipment sector

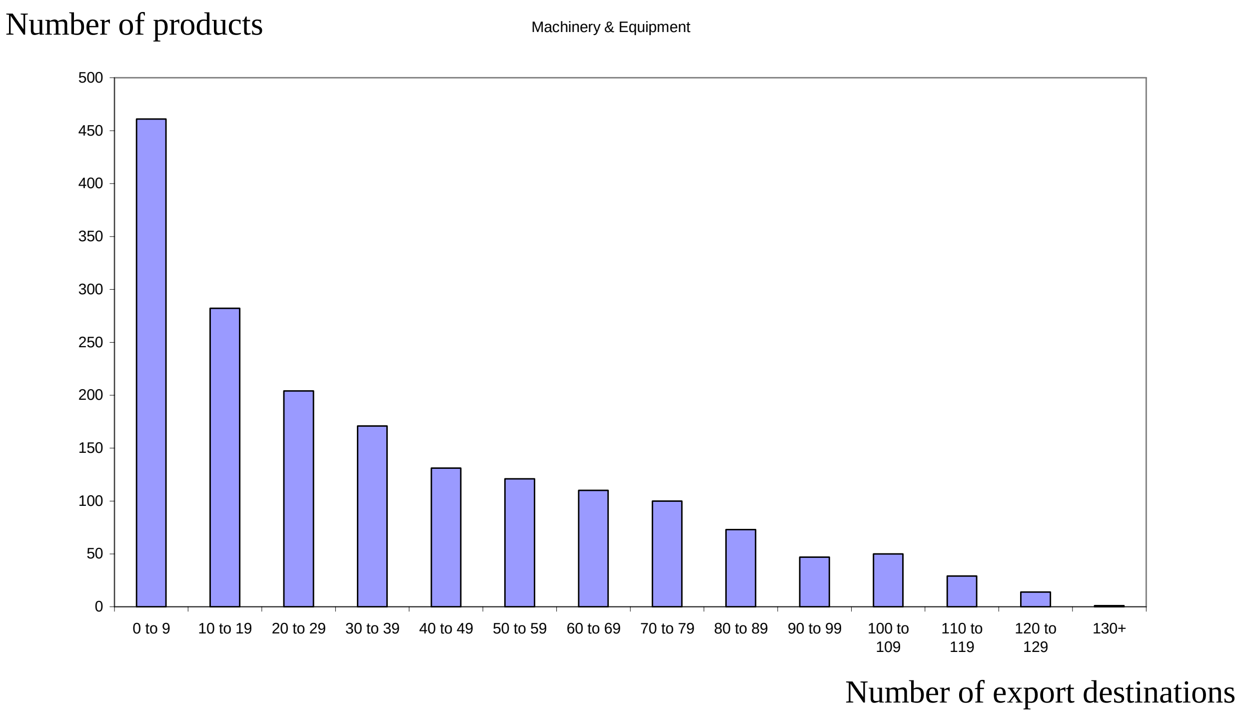

Figure 2a Unit value and GDP per capita for Absorbent gauze or muslin bandages (30059010)

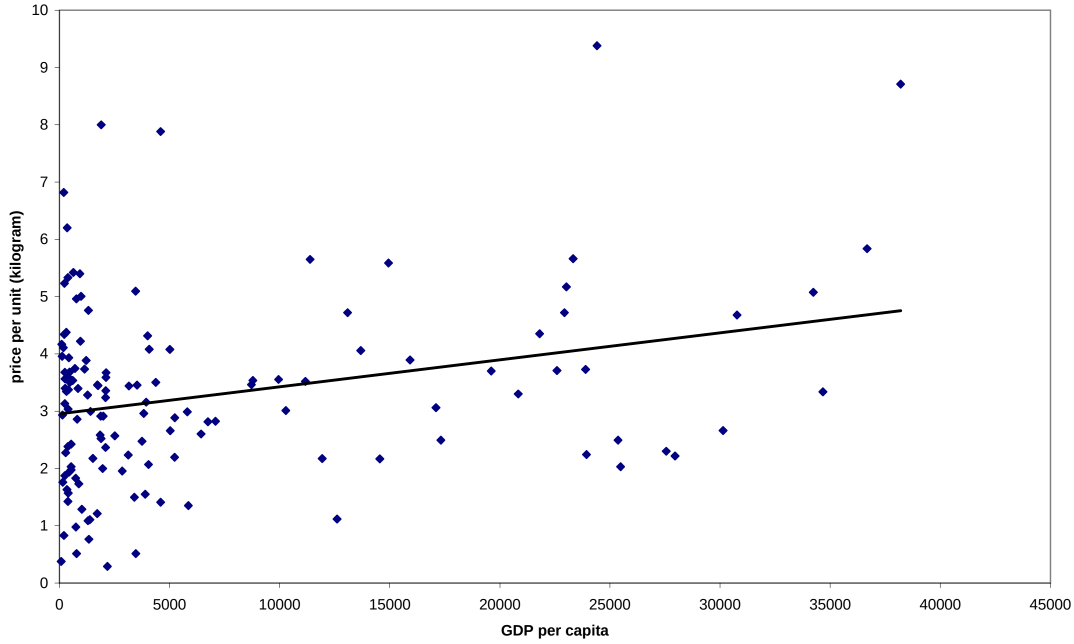

Figure 2b Unit value and GDP per capita for Motorcycles with reciprocating internal combustion piston engine, 50-250cc (87112000)

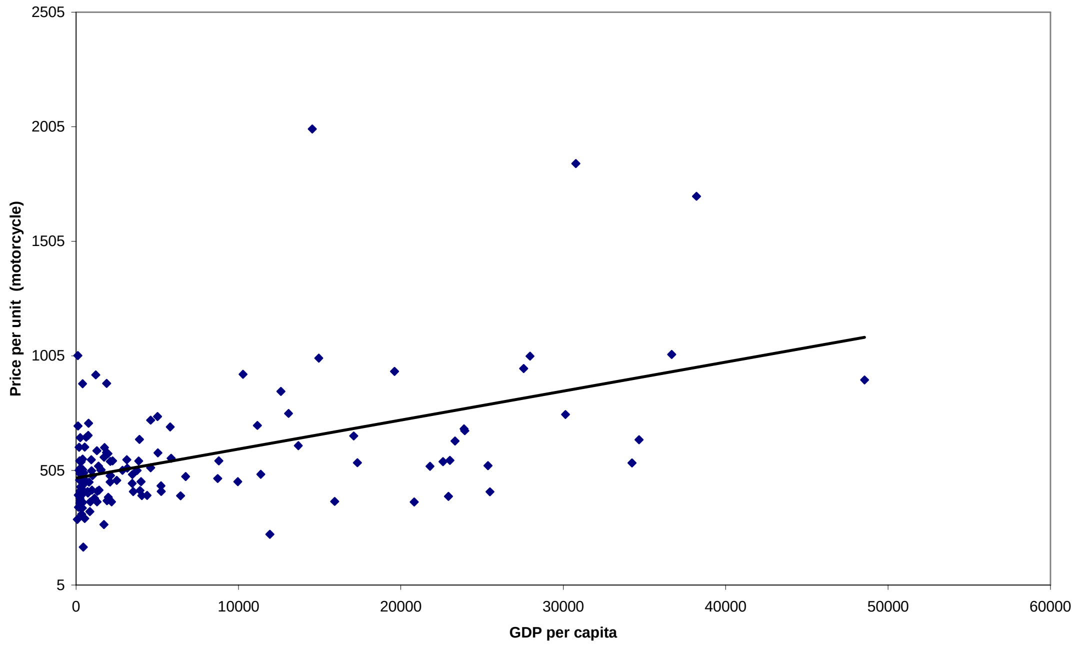

Table 1. Summary of existing evidence and theory on the link between unit value and country characteristics

Variable		**Sign**	**Empirical Evidence**	**Theoretical Interpretation**
Distance/ transport costs		+	(a) Hummels and Skiba (2004) (b) Baldwin and Harrigan (2007) (c) Harrigan and Deng (2008)	(a) Alchien-Allen Effect (b) Heterogeneous Firms with quality selection
Market Size	Importer	-	Baldwin and Harrigan (2007)	Heterogeneous Firms with quality selection
	Exporter	+/-	Hummels and Klenow (2005)	
Per Capita Income	Importer	+	Hummels and Skiba (2004) Harrigan and Deng (2008)	Quality differentiation and Non-homothetic preference
	Exporter	+	(a) Schott (2004) (b) Hummels and Skiba (2004) (c) Hummels and Klenow (2004) (d) Hallak (2006)	

Table 2: Predictions on Market Size , Distance and export unit value from Baldwin-Harrigan (2007)

Model	**Effect of Distance**	**Effect of Market Size**
Quality sorting $\sigma > 1$	+	-
Efficiency Sorting $\sigma > 1$:	-	+

Table 3: HS 2-digit Industries and their Description

HS Code	Description	Observations
1-5	Live animals and animal products	3,893
6-14	Vegetable products	12,248
15	Fats oils and waxes	608
16-24	Food products, beverages & tobacco	9,192
25-27	Mineral products	5,320
28-38	Chemicals	54,641
39-40	Plastics and rubber	18,464
41-43	Leather, fur etc.	5,625
44-46	Wood and Wood products	6,177
47-49	Wood pulp, paper and paper articles	9,131
50-63	Textiles	83,214
64-67	Footwear, headwear etc.	8,791
68-70	Glass, glassware, stone and ceramics	16,713
71	Pearls, precious metals and jewellery	1,417
72-83	Base metals	49,766
84-85	Machinery, mechanical, electrical equipment	91,336
86-89	Vehicles, aircraft and transportation equipment	11,505
90-92	Clocks, watches and specialist instruments	22,140
94-96	Other manufactured goods	25,773

Table 4: Results for Market Size and Distance in a Regression for Average Unit Value by HS 2-digit Industries

Description	*Distance*	*Market Size*	*HS8 codes*	*Obs.*
	Positive	**Positive**		
Live animals and animal products	0.099 (4.88)***	0.063 (5.94)***	260	3507
Vegetable products	0.148 (12.48)***	0.026 (4.68)***	472	10487
Food products, beverages & tobacco	0.057 (5.11)***	0.020 (4.30)***	270	8146
Mineral products	0.242 (13.18)***	0.022 (2.43)**	186	4431
Wood and Wood products	0.128 (8.92)***	0.021 (3.55)***	129	5547
Wood pulp, paper and paper articles	0.081 (4.98)***	0.020 (3.09)***	192	6965
Textiles	0.076 (16.95)***	0.041 (23.47)***	1150	77851
Glass, glassware, stone and ceramics	0.106 (8.69)***	0.032 (6.77)***	180	14729
Base metals	0.036 (6.22)***	0.024 (10.92)***	680	44816
Plastics and rubber	0.014 (1.33)	0.035 (8.67)***	271	15923
Footwear, headwear etc.	0.085 (4.69)***	0.004 (0.73)	60	8147
Chemicals	0.086 (12.43)***	0.002 (0.61)	1157	50229
	Positive	**Negative**		
Pearls, precious metals and jewellery	0.342 (4.62)***	-0.089 (2.68)***	169	1234
Other manufactured goods	0.009 (0.84)	-0.020 (5.38)***	176	23250
Leather, fur etc.	0.052 (2.46)**	-0.001 (0.07)	127	5183
Fats oils and waxes	0.065 (1.18)	-0.018 (0.70)	39	522
	Negative	**Negative**		
Machinery, mechanical, electrical equipment	-0.063 (7.83)***	-0.016 (4.97)***	1370	77746
Clocks, watches and specialist instruments	-0.042 (2.53)**	-0.021 (2.97)***	310	18694
Vehicles, aircraft and transportation equipment	-0.022 (1.42)	-0.017 (3.29)***	232	10147

Notes: + significant at 10%; * significant at 5%; ** significant at 1%. This is an OLS regressions using HS8 product fixed effects. It additionally includes measures of common borders, GDP per capita and separate time dummies for the years 1997, 2000 and 2002.

Table 5: Predictions from a heterogeneous firm trade model with quality differences and spatial price discrimination

Quality Sorting (>1) Model			
Relationship with	*Selection Effect*	*Price discrimination Effect*	*Total Effect*
Distance	+	-	+ / -
Market Size	+	-	+/-
Efficiency Sorting (<1) model			
Relationship with	*Selection Effect*	*Price discrimination Effect*	*Total Effect*
Distance	-	-	-
Market Size	-	-	-

Table 6. Summary of Empirical findings and their theoretical interpretation

Sign on coefficient for Market size and Distance	Sorting pattern implied	Comment	Empirical Evidence for China
+ +	Quality sorting	Selection effects dominates	Majority of Chinese industries
+ -	Quality sorting	Selection (price discrimination) effect dominates for distance (market size),	One Chinese industry (plus US exports)
- -	Efficiency sorting or quality sorting	Price discrimination effect dominates	Two Chinese industries
- +	Quality sorting	Price discrimination (Selection) effect dominates for distance (market size)	No evidence

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Appendix

Table A1 : Number of HS8 products exported to each country from China

country	No of HS8 products	country	No of HS8 products	country	No of HS8 products	country	No of HS8 products
Algeria	2,997	El Salvador	1,722	Laos	744	Saudi Arabia	6,170
Angola	1,263	Ethiopia	2,441	Liberia	453	Senegal	1,122
Argentina	4,712	Fiji	1,769	Madagascar	2,162	Seychelles	499
Australia	9,849	Finland	4,281	Malawi	416	Sierra Leone	574
Austria	3,366	France	7,813	Malaysia	10,325	Singapore	11,096
Bahamas	227	Gabon	506	Mali	494	Solomon Islands	443
Bahrain	1,883	Gambia	774	Malta	1,898	South Africa	7,176
Bangladesh	5,772	Germany	10,050	Mauritania	583	Spain	7,546
Belize	514	Ghana	2,810	Mauritius	3,222	Sri Lanka	4,952
Benin	1,860	Greece	5,438	Mexico	5,253	St Kitts and Nevis	29
Brazil	5,774	Guatemala	2,624	Mongolia	2,808	Sudan	2,614
Bulgaria	2,331	Guinea	1,054	Morocco	3,820	Suriname	1,520
Burkina Faso	258	Guinea Bissau	93	Mozambique	1,052	Sweden	4,778
Burundi	203	Guyana	1,076	Nepal	1,560	Switzerland	4,171
Cameroon	1,521	Haiti	565	New Zealand	6,016	Syrian Arab Republic	3,525
Canada	8,603	Honduras	1,700	Nicaragua	896	Tanzania	2,258
Central African Republic	94	Hong Kong	14,984	Niger	189	Thailand	9,262
Chad	50	Hungary	3,709	Nigeria	4,743	Togo	1,093
Chile	5,757	Iceland	566	Norway	3,616	Trinidad And Tobago	1,665
Colombia	3,213	India	7,161	Oman	1,298	Tunisia	2,661
Comoros	49	Indonesia	9,464	Pakistan	6,668	Turkey	5,579
Congo	994	Iran	4,594	Panama	4,228	USA	13,313

Costa Rica	2,081	Iraq	16	Papua New Guinea	1,897	Uganda	895
Cote D'Ivour	1,835	Ireland	2,572	Paraguay	1,720	UAE	7,953
Cyprus	2,914	Italy	8,957	Peru	3,796	UK	9,210
Czechoslovakia	3,398	Jamaica	1,480	Philippines	8,242	Uruguay	3,108
Denmark	4,501	Japan	14,019	Poland	4,579	Venezuela	3,860
Djibouti	1,067	Jordan	4,491	Portugal	3,673	Yemen	3,094
Dominican Republic	2,170	Kenya	3,225	Romania	3,394	Zambia	1,077
Ecuador	3,026	Korea RP	12,541	Rwanda	276	Zimbabwe	1,554
Egypt	6,056	Kuwait	3,620				