Trade and Prices with Heterogeneous Firms*

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Abstract

This paper estimates a heterogeneous firms trade model using disaggregate data on export values and prices. Prices contain information about differences in product quality across firms and countries that helps identify key mechanisms in the model. Examining within-country variation in export prices across destination markets, I find that prices behave in a manner inconsistent with the benchmark model that ignores product quality differences across firms. In doing so, I demonstrate that export prices in most sectors are consistent with a model in which high productivity firms choose to produce high quality goods and charge high prices. Using model estimates, I also quantify the role of endogenous non-tradability in accounting for variation in prices and trade flows, and construct an index of cross-country quality and variety within sectors.

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1 Introduction

A substantial volume of empirical research in international trade has documented that exporting firms are systematically different than non-exporters. They are larger, more productive, more skill and capital intensive, and pay higher wages than non-exporters.¹ Further, there is a strong hierarchy among firms and destination markets, with only the largest, most capable firms exporting to difficult foreign markets.² Identifying the underlying sources of these differences would lead to improved understanding of important questions regarding the pattern of trade and the effects of trade frictions, as well as contribute to improved aggregate theories of trade adjustment, the real exchange rate, and international fluctuations. While much progress has been made on these fronts, much remains to be done.

One important gap within this rapidly expanding literature concerns export prices. Prices contain valuable information to refine our understanding of the causes and consequences of trade. Specifically, prices provide evidence about the extent of vertical specialization and quality heterogeneity within sectors and across countries. As Schott (2004) and Hummels and Klenow (2005) report, export prices are systematically correlated with source country characteristics, such as income per capita and the capital/skill intensity of production. In addition, this paper documents that prices vary across destination markets for a given exporter in a manner that provides insight into the nature of firm heterogeneity. Thus, prices allow us to identify fundamental determinants of trade. Additionally, determining whether heterogeneous firms trade models provide accurate empirical price predictions is an important input toward determining how these models can and should be used to study the aggregate consequences of endogenous non-tradability.

To unlock the information in prices, this paper estimates a structural model of trade with heterogeneous firms and endogenous quality using sector-level data on manufacturing trade and prices. The empirical approach is guided by two overarching questions. First, does the standard formulation of the model provide predictions for export prices that are consistent with available data? Second, using the model to impose structure on the data, what do we learn about the deep determinants of trade and prices?

To answer these questions, I augment a leading heterogeneous firms model – the Melitz model – to allow firms to choose the level of quality of the good they produce, subject to costs of upgrading quality. In the model, higher productivity firms optimally choose to produce higher quality goods. As a result, productivity has countervailing effects on prices. On the one hand, higher productivity directly lowers prices by driving down the marginal cost of production. On

¹See Bernard, Redding, and Schott (2007) for a recent survey article documenting these facts.

²See Eaton, Kortum, and Kramarz (2004, 2007) for firm level evidence from France.

the other hand, higher productivity induces the firm to upgrade quality, which in turn raises marginal costs and hence prices. Whether high productivity firms charge absolutely higher or lower prices than low productivity firms depends on the strength of incentives to upgrade quality. This contrasts with the benchmark formulation of the Melitz model with homogeneous quality in which higher productivity translates one for one into lower prices.³

In addition to choosing quality, firms decide whether to export. To enter foreign markets, firms incur destination-specific fixed costs. As a result, they self-select into exporting and non-exporting groups according to whether they surpass a destination-specific productivity threshold for exporting. Variation in this threshold across destination markets then generates within-country variation in the number of exporting firms, aggregate exports, and the average price of exports. Moreover, because the average productivity of exporting firms varies across markets as a function of the productivity threshold, within-country variation in observed aggregate export prices across destinations reveals how firm-level prices vary with productivity. Correspondingly, export price variation also reveals how strongly quality covaries with firm level productivity.

I bring together sector-level data on prices, export participation, and trade volumes to estimate the three main structural components of the augmented model. Following Helpman, Melitz and Rubinstein (2007), I exploit binary, sector-level data on participation in trading relationships to estimate relative export productivity thresholds for each country against alternative destination markets. I then proceed to estimate joint structural equations that relate bilateral export volumes and export prices to the estimated thresholds. The price equation, based on the aggregation of firm-level prices, relates observed export prices to home country characteristics and partner specific export thresholds. As in Helpman, Melitz and Rubinstein, the trade equation is a gravity-style specification derived from the demand structure that accounts for both variation in the set of firms engaged in trade across partners and endogenous selection into bilateral trade relationships.

Confronting the model with the data, I find that export prices behave in a manner inconsistent with the benchmark, homogeneous quality formulation of the Melitz model. The benchmark model makes the counterfactual prediction that the price at which a country exports should be decreasing in the productivity threshold for exporting to the destination market. In the data, export prices are increasing in the productivity threshold for the majority of sectors. That is, export prices are higher on average to difficult export destinations. While inconsistent with the benchmark model, the data are consistent with my quality-augmented model. In my model, high productivity firms charge higher unit prices when the incentive to upgrade quality is strong enough to overcome the direct effect of higher productivity on unit prices. Because these high

³Melitz (2003), Chaney (2007), Ghironi and Melitz (2005), Helpman, Melitz and Rubinstein (2007), and many others employ this benchmark formulation.

productivity firms are the only firms able to profitably serve difficult markets, export prices will be increasing in the export productivity threshold. Thus, the flexibility introduced by within-country variation in product quality across firms helps make sense of the data.

While export prices are increasing in the productivity threshold in most sectors, I also find that prices in a subset of related sectors behave in a manner more consistent with the benchmark model. These sectors include apparel, footwear, and electronic appliances. According to my model, these sectors should be ones in which large firms charge low unit prices either because the benefits of quality upgrading are small or the cost of upgrading quality is steep. Interestingly, Khandelwal (2007) argues that these products are characterized by relatively short “quality ladders,” meaning that the scope for quality upgrading in these sectors is limited compared to long quality ladder industries like chemicals, for example, where I find that prices rise with the productivity threshold. This external evidence is suggestive that quality-upgrading can explain the price patterns I document in the data.

Having established the relationship between productivity thresholds and prices, I proceed to study the quantitative importance of threshold variation in explaining both prices and trade patterns. In practice, productivity thresholds play a relatively small quantitative role in understanding price variation, both within and across exporters. Rather, variation exporter-specific factors, common to all destination markets that a given exporter serves, explain a large portion (about one-half) of the overall variation in prices. Furthermore, the estimated exporter-specific component of prices is highly correlated with source country income. To a first approximation, the export price schedule for a rich country is shifted upward relative to the price schedule of a poor country. As such, this suggests large variation in average product quality across countries within sectors.⁴

In contrast to prices, productivity cutoffs account for a large portion (approximately 40%) of the overall variation in exports.⁵ This suggests that variation in the number and characteristics of exporting firms plays a large quantitative role in explaining aggregate export patterns. To shed further light on the determinants of trade patterns, I use the estimated exporter-specific component of prices to recover a quality/variety composite from the exporter-specific component of the trade equation. This composite provides evidence that quality/variety heterogeneity across countries can explain much of the variation in aggregate export volumes within sectors across countries.

⁴These results accord well with facts documented for US imports by Schott (2004), as well as work in progress by Hallak and Schott (2005) that emphasizes product quality differences as the prime determinant of cross country price differences.

⁵Consistent with Helpman, Melitz, and Rubinstein (2007), controlling for variation in productivity thresholds diminishes the direct role of trade frictions in explaining trade patterns in the sector-level data.

1.1 Related Literature

In contrast to the emphasis on prices in this paper, previous empirical work on models with endogenous non-tradability has mostly been confined to studying trade flows and export participation decisions. Recent papers have documented selection into exporting,⁶ studied the assignment of firms and firm-level exports to specific destination markets,⁷ examined firm and industry responses to trade frictions and liberalization,⁸ and explored the dynamics firm-level and aggregate exports.⁹ Within this literature, this paper draws most heavily on the insights and estimation framework of Helpman, Melitz, and Rubinstein (2007). In a departure from their paper, I endogenize product quality and extend their methodology to use information on prices in estimating the model. Further, whereas Helpman, Melitz and Rubinstein focus on aggregate trade patterns, I shift emphasis toward studying disaggregated sectoral flows that more closely match the industrial structure assumed in the model.¹⁰

Relatively less work has been dedicated to the price implications of this class of models. Ghironi and Melitz (2005), Bergin and Glick (2006), and Bergin, Glick, and Taylor (2006) study the behavior of the real exchange rate in models with endogenous non-tradability.¹¹ Atkeson and Burstein (2007) use a model with endogenous non-tradability, imperfect competition, and pricing-to-market to study short-run fluctuations of cross-country consumer and producer prices. Importantly, these contributions have focused primarily on calibration and simulation to study aggregate empirical predictions. This paper is among the first to exploit disaggregated unit value price data to assess the price predictions of these models.

Most closely related to this paper, contemporaneous independent work by Baldwin and Harrigan (2007) explores how information contained in the incidence of export zeros and export prices in U.S. bilateral data helps distinguish between alternative models of international trade, including Helpman-Krugman, Eaton-Kortum, and Melitz style trade models. They provide evidence that trade costs are an important determinant of differences in trade participation across

⁶For example, see Bernard and Jensen (1995), Bernard and Jensen (1999), and Bernard, Jensen, Eaton and Kortum (2003) on selection.

⁷For example, see Arkolakis (2007) and Eaton, Kortum, and Kramarz (2007).

⁸On the empirical side, see Bernard, Jensen, and Schott (2006) on responses to declines in trade costs and Bustos (2007) on firm-level reactions to MERCOSUR. Chaney (2007) examines responses to frictions on intensive versus extensive margins at the industry level from a theoretical perspective.

⁹See Roberts and Tybout (1997), Bernard and Jensen (2004), Das, Roberts, and Tybout (2007), and Eaton, Eslava, Kugler, and Tybout (2007) on the dynamics of entry and exit among exporters. Ruhl (2005) and Alessandria and Choi (2007) study the effects of sunk export costs and hysteresis on trade dynamics in calibrated models.

¹⁰Manova (2007) also uses sector-level trade flows in estimating a Helpman, Melitz and Rubinstein style model to study the influence of credit constraints on trade.

¹¹See also Rodriguez-Lopez (2006) for a model of exchange rate pass-through with endogenous non-tradability and sticky prices.

industries and argue that all three existing models are inconsistent with the data.¹² Further, they suggest that a quality-augmented Melitz model might be able to rationalize the data. Also related to this paper is work in progress by Hallak and Sivadasan (2006) that incorporates endogenous quality choices into a Melitz style model of trade with minimum quality requirements for exporting in order to study microdata on the characteristics of exporting versus non-exporting firms. Importantly, they present firm-level evidence from Chile, Colombia, and India suggesting that exporters in these countries produce higher quality goods than non-exporting firms. Their paper thus provides micro-based evidence that supports the emphasis on quality differences that this paper appeals to in order to understand multi-country, sector-level aggregates.

2 Theory

In this section I introduce a multi-country model of trade in a continuum of differentiated products. The basic setup of the model follows Melitz (2003) and Helpman, Melitz, and Rubinstein (2007) closely in conceptualizing the firm-level decision to export. The model here deviates from this previous work by introducing endogenous product quality in a manner similar to Hallak and Sivadasan (2006) and focusing attention on the price implications of the model. To simplify the presentation, I exposit the main results on prices and exports relevant to estimation of the model in the main text and relegate details (including the equilibrium definition) to Appendix A. Further, to reduce notational clutter, I focus on a one-sector version of the model (e.g., aggregate manufacturing). In the empirical work, I straightforwardly extend the framework to multiple sectors.

2.1 Consumption

To begin, assume that there is a representative consumer in each country with constant elasticity of substitution (CES) preferences over consumption of differentiated varieties of manufactures given by:

$$C_i = \left(\int_{\omega \in \Omega_i} [\lambda(\omega) c_i(\omega)]^{(\sigma-1)/\sigma} d\omega \right)^{\sigma/(\sigma-1)},$$

where ω indexes an individual variety among the set Ω_i of varieties available in country i , $\lambda(\omega)$ is the quality of variety ω , $c_i(\omega)$ is the quantity consumed, and $\sigma > 1$ is the elasticity of

¹²Baldwin and Harrigan report that both U.S. export prices and the number of zero-export observations at the HS 10-digit level are increasing in distance to foreign markets, controlling for aggregate GDP and the GDP per capita of the destination market. They also report that the incidence of zeros is negatively related to destination income. These facts are consistent with the results obtained in this paper. Using a differences in differences procedure, they also show that changes in trade costs across industries explain changes in the prevalence of export zeros across sectors.

substitution between varieties. Product quality here enters as a demand shifter in preferences, such that higher quality goods (larger $\lambda(\omega)$) yield higher consumption utility. As a result, if two varieties with different quality levels have identical prices, a maximizing consumer allocates a larger share of expenditure to the higher quality good.

Preferences are assumed to be identical across countries.¹³ With a price $p_i(\omega)$ for variety ω in country i , the consumer will allocate consumption according to:

$$c_i(\omega) = [\lambda(\omega)]^{\sigma-1} \left(\frac{p_i(\omega)}{P_i} \right)^{-\sigma} C_i,$$

where $P_i = \left(\int_{\omega \in \Omega_i} [p_i(\omega)/\lambda(\omega)]^{1-\sigma} d\omega \right)^{1/(1-\sigma)}$ is the CES aggregate price level of consumption. The remaining assumptions are standard. The consumer inelastically supplies L_i units of labor to firms and receives wage w_i . Aggregate spending $P_i C_i$ equals aggregate labor income $w_i L_i$.

2.2 Production

Each variety of the differentiated good is produced by an individual monopolistically competitive firm. These firms are heterogeneous with respect to idiosyncratic physical productivity $z(\omega)$, which is measured relative to aggregate productivity Z_i in the country where the firm resides. The number of firms actively producing in each country is N_i .

In addition to choosing the price of their output, each firm also chooses the quality $\lambda(\omega)$ of the good it produces subject to costs of upgrading quality. I assume the firm pays $f_i(\lambda)$ to choose quality level λ , with $f'_i(\lambda) > 0$. Thus, the cost of upgrading rises with the level of quality chosen and is independent of the quantity of goods the firm produces.¹⁴ Denote this fixed cost $f_i(\lambda)$ with $f'_i(\lambda) > 0$.¹⁵ Further, for analytical tractability, I assume that the firm chooses quality after entry based on the revenue generated via sales in its home market only.¹⁶ In producing output, firms employ a constant returns to scale technology with a marginal cost function that depends on the quality of the good produced. For a firm in country i , marginal

¹³Implicitly, these preferences assume that individuals everywhere have identical perceptions of product quality and/or tastes for each variety. Allowing for different tastes for quality is a natural direction for future work.

¹⁴The assumption that producing higher quality goods entails higher fixed cost follows a prominent line of the industrial organization literature. See Sutton (2007) for a recent application of this literature to international trade.

¹⁵The subscript i recognizes that this fixed cost may be country specific. The exact dependence of the fixed cost on country characteristics will be made clear below and plays a minor role in the analysis.

¹⁶This assumption is necessary to generate a quality schedule that is a smooth function of productivity and permits aggregation. In the event that firms choose quality with an eye toward participation in foreign markets, then quality choices are discontinuous in z since fixed export costs generate discontinuities in revenue as a function of z . While this extension would complicate the analysis, it does not change the basic prediction of the model.

cost is given by $MC_i(z(\omega), \lambda(\omega))$.

As is standard in monopolistic competition models with CES preferences, prices are set as a constant markup over marginal cost: $p_i(\omega) = \frac{\sigma}{\sigma-1} MC_i(z(\omega), \lambda(\omega))$. Conditional on this optimal pricing rule, the firm chooses its quality level to maximize operating profits in its home market. A firm producing variety ω will choose $\lambda(\omega)$ to solve:

$$\begin{aligned} \max_{\{\lambda(\omega)\}} \quad & p_i(\omega)c_i(\omega) - MC_i(z(\omega), \lambda(\omega))c_i(\omega) - f_i(\lambda(\omega)) \\ \text{s.t.} \quad & c_i(\omega) = [\lambda(\omega)]^{\sigma-1} \left(\frac{p_i(\omega)}{P_i} \right)^{-\sigma} C_i \\ \text{and} \quad & p_i(\omega) = \frac{\sigma}{\sigma-1} MC_i(z(\omega), \lambda(\omega)), \end{aligned} \tag{1}$$

taking P_i, C_i as given. With this setup, any two firms with identical idiosyncratic productivity will choose identical quality levels. Hence shifting notation, each firm can be equivalently characterized by the pair $\{z, \lambda(z)\}$, where $\lambda(z)$ is the quality of the product produced by firm with productivity level z .

To make progress in evaluating this problem, I proceed to make parametric assumptions regarding the form of the marginal cost function and the fixed cost of quality upgrading. To discipline these assumptions, I appeal to the wealth of empirical evidence that firm sizes follow a Pareto distribution. To generate this fact in the model, I assume that a firm with productivity z in country i produces using labor input with marginal cost $MC_i(z) = \frac{w_i \lambda(z)^\beta}{Z_i z}$, where w_i is the price of labor.¹⁷ The parameter β indexes the elasticity of marginal cost with respect to quality. As for the fixed cost, I assume that $f_i(\lambda) = \frac{w_i \lambda^\phi}{Z_i} f_i$, where ϕ indexes the elasticity of fixed costs with respect to quality. I impose the parameter restriction $0 < (1 - \beta)(\sigma - 1) < \phi$ to guarantee that a maximum exists and that quality choice is strictly positive. This restriction combines three elements. First, fixed costs are increasing in quality ($\phi > 0$). Second, quality-adjusted prices are falling in quality ($\beta < 1$). Third, the elasticity of substitution (σ) is not so large that it creates benefits of upgrading quality that overwhelm the cost of quality upgrading. This ensures that there are diminishing returns to raising quality.

¹⁷Drawing on Verhoogen (forthcoming), one interpretation of this technology is that a firm producing a good with quality $\lambda(z)$ needs to employ workers with skill level equal to $\lambda(z)^\beta$ times the skill level of workers needed to produce one unit of output of a good with quality level equal to one.

With these assumptions, a firm with productivity level z chooses product quality to solve:

$$\begin{aligned} \max_{\{\lambda\}} \quad & p_i(z)c_i(z) - \left[\frac{w_i\lambda^\beta}{Z_i z} \right] c_i(z) - \frac{w_i\lambda^\phi}{Z_i} f_i \\ \text{s.t.} \quad & c_i(z) = [\lambda]^{\sigma-1} \left(\frac{p_i(z)}{P_i} \right)^{-\sigma} C_i \\ \text{and} \quad & p(z) = \left(\frac{\sigma}{\sigma-1} \right) \frac{w_i\lambda(z)^\beta}{Z_i z}. \end{aligned} \quad (2)$$

The optimal choice of quality for a firm with productivity z (denoted $\lambda^*(z)$) is:

$$\lambda^*(z) = \left[\frac{1-\beta}{\phi f_i} \left(\frac{\sigma}{\sigma-1} \frac{w_i}{Z_i} \right)^{-\sigma} P_i^\sigma C_i \right]^{1/(\phi-(1-\beta)(\sigma-1))} z^{(\sigma-1)/(\phi-(1-\beta)(\sigma-1))}.$$

Defining $\lambda_i \equiv \left[\frac{1-\beta}{\phi f} \left(\frac{\sigma}{\sigma-1} \frac{w_i}{Z_i} \right)^{-\sigma} P_i^\sigma C_i \right]^{1/(\phi-(1-\beta)(\sigma-1))}$ and $\alpha = \frac{\sigma-1}{\phi-(1-\beta)(\sigma-1)}$, then I can rewrite the optimal quality choice in terms of a country-specific component and a firm-specific component:

$$\lambda_i^*(z) = \lambda_i z^\alpha. \quad (3)$$

Quality is increasing in productivity since $\phi - (1 - \beta)(\sigma - 1) > 0$ implies $\alpha > 0$. This has a natural intuition. Because choosing quality entails higher fixed costs, large firms with high productivity in the model will have lower costs of quality upgrading per unit and hence choose higher quality.

A number of results about the distribution of firm sizes and the schedule of prices follow from this quality choice result. To start, I use the quality schedule in (3) to write prices as:

$$p_i(z) = \left(\frac{\sigma}{\sigma-1} \frac{w_i}{Z_i} \right) \left(\frac{\lambda_i^\beta}{z^{1-\alpha\beta}} \right). \quad (4)$$

Then, defining the quality-adjusted price of a good produced with productivity z as $\tilde{p}_i(z) = \frac{p_i(z)}{\lambda_i^*(z)}$, I write quality-adjusted prices as:

$$\tilde{p}_i(z) = \left(\frac{\sigma}{\sigma-1} \frac{w_i}{Z_i} \right) \left(\frac{\lambda_i^{\beta-1}}{z^{1-\alpha\beta+\alpha}} \right). \quad (5)$$

The parameter restrictions discussed above imply that $1 + \alpha - \alpha\beta > 0$. This means that high productivity firms always charge lower quality adjusted prices than low productivity firms. As a corollary, higher productivity firms have higher revenues than low productivity firms when they

compete in the same market.

The first result regarding the firm size distribution is almost immediate. To see it, note that firm revenue in the domestic market is a function of quality-adjusted prices: $R_i(z) = \left(\frac{\tilde{p}_i(z)}{P_i}\right)^{1-\sigma} E_i$, where $E_i = P_i C_i$ is total expenditure in country i . Then, firm sizes are Pareto if $\tilde{p}_i(z)$, and hence z , is Pareto. As in Helpman, Melitz, and Rubinstein (2007), I will therefore assume that firms draw their individual z from a truncated Pareto distribution.¹⁸ The CDF and PDF of the distribution in each country i is given by:

$$\begin{aligned} G(z) &= \frac{z^{-k} - z_L^{-k}}{z_H^{-k} - z_L^{-k}} \\ g(z) &= \frac{kz^{-k-1}}{z_L^{-k} - z_H^{-k}}, \end{aligned} \tag{6}$$

with finite support $z \in [z_L, z_H]$. The shape parameter k governs the distribution of productivities and is assumed to be common across countries within an industry. A large value of k indicates that the distribution has a “thin” tail and generates less dispersion overall in productivities across firms. For simplicity, I assume that the upper bound on the distribution of relative productivities (z_H) is equal across countries. Since variation in z_H across countries is observationally equivalent to allowing aggregate productivity to be country specific, restricting z_H in this manner does not result in loss of generality.¹⁹

The second set of results about the schedule of prices are important both for understanding how export prices behave and how this model relates to more standard setups in the literature. In this endogenous quality model, high productivity firms choose to produce higher quality goods and have lower quality adjusted prices. On the other hand, whether larger firms have higher or lower unit prices is indeterminate. Rather, the slope of the schedule of absolute prices with respect to productivity is governed by the strength of the quality upgrading channel. In terms of the model, the key point is that the unit price of firm z ’s good is increasing in z only if $\alpha\beta > 1$ – equivalently, $\phi < (\sigma - 1)$ – and decreasing otherwise. This means that quality upgrading is inexpensive relative to the demand side benefits of raising quality, and hence that higher productivity firms will choose to aggressively upgrade quality. Thus, sectors in which $\phi < (\sigma - 1)$ will be sectors in which productivity dispersion will lead to a large degree of quality dispersion. Furthermore, in these sectors the quality upgrading effect will outweigh the direct

¹⁸Note that all firms that choose to enter and draw a productivity level actually produce ex post. Thus, the minimum productivity cutoff in the model is exogenous, unlike in Melitz (2003). This may be relaxed without changing the main implications of the model considered in this paper.

¹⁹Note that as $z_H \rightarrow \infty$, then the distribution approaches $G(z) = 1 - \left(\frac{z_L}{z}\right)^k$. This is simply a special case of this formulation, but one that has counterfactual implications for export participation. Namely, $z_H \rightarrow \infty$ implies that we should observe every country trading with every other country – a result clearly at odds with the data.

influence of marginal cost on prices. Alternatively, in sectors with $\phi > (\sigma - 1)$ there will be less quality dispersion for a given degree of productivity dispersion and hence the direct effects of productivity will tend to dominate in determining prices.

To see the merits of this formulation, it is helpful to contrast the model with the standard version of the Melitz model, as exemplified by Melitz (2003), Ghironi and Melitz (2005) and Helpman, Melitz and Rubinstein (2007). In those models, firms have heterogeneous productivity, but quality is homogeneous across firms (normalized to $\lambda(z) = 1 \forall z$). As a result, prices are given by $p_i(z) = \left(\frac{\sigma}{\sigma-1} \frac{w_i}{Z_i z} \right)$ and more productive firms always charge lower prices. An alternative formulation of this type of model – suggested in passing in Melitz (2003, p.1699) – is one in which firms are costlessly endowed with heterogeneous quality and have identical marginal costs of production. In that alternative model, unit prices would be identical across all firms.

In contrast to these benchmark formulations, the more flexible model in this paper allows the schedule of unit prices to be either increasing or decreasing in z depending on the strength of the quality upgrading channel in different sectors. Put differently, quality needs to be both increasing in productivity and increasing strongly enough to overcome the direct influence of productivity on prices in order to find that larger, more productive firms are charging higher prices per unit. In economic terms, this means that high productivity firms must find it profitable to strongly upgrade quality and therefore charge higher absolute prices, rather than compete on price alone.

2.3 Selection into Exporting and Export Prices

Firms incur trade costs when they export. In particular, they face both a fixed cost to enter each specific export market and a variable iceberg trade cost to serve that market. For a firm from country i to export to country j it must pay a fixed cost equal to f_{xij} and must ship $\tau_{ij} > 1$ units of the good for one unit to arrive for consumption in j . Defining $q_{ij}(z)$ as the quantity of goods shipped, then $c_{ij}(z) = \frac{q_{ij}(z)}{\tau_{ij}}$. If the factory gate price for produced output is $p_i(z)$ then the consumer price of one unit of consumption of that good in the foreign country is $p_{ij}(z) = \tau_{ij}p_i(z)$. Firm revenue from exporting to country j is then given by:

$$R_{xij}(z) = p_i(z)q_{ij}(z) = \left(\frac{\tilde{p}_i(z)\tau_{ij}}{P_j} \right)^{1-\sigma} E_j \quad (7)$$

where P_j is the sectoral price index in country j , $E_j = P_j C_j$ is sectoral expenditure in j , and $\tilde{p}_i(z) = p_i(z)/\lambda_i(z)$ is the quality-adjusted price (exclusive of trade costs).

Firms select into exporting to market j if they earn positive profits from exporting. With optimal pricing, operating profits from exporting excluding the fixed cost are equal to $\frac{1}{\sigma} R_{xij}(z)$.

Then, a firm with productivity z exports if:

$$\frac{1}{\sigma} R_{xij}(z) \geq f_{xij}. \quad (8)$$

For each market, this condition implies that there exists a marginal firm with threshold productivity z_{xij} such that (8) holds with equality. The quality adjusted price of the marginal firm is then given by:

$$\tilde{p}_c(z_{xij}) = \frac{P_j}{\tau_{ij}} \left(\frac{E_j}{\sigma f_{xij}} \right)^{1/(\sigma-1)}. \quad (9)$$

Note that revenue and selection into exporting depend on a firm having a low quality-adjusted price. Only low quality-adjusted price firms are able sell enough to recoup the fixed costs f_{xij} of entering the foreign market. Conditional on fixed costs, foreign markets that are either larger (higher E_j), less competitive (higher P_j), or have lower variable trade costs (τ_{ij}) generate higher revenue for any given firm that enters, and thus these features of the destination market allow firms with higher quality adjusted prices to recoup the fixed costs of entry. The existence of a threshold quality-adjusted price for exporting similarly implies that there is a threshold productivity for exporting to market j that satisfies:

$$z_{xij} = \left[\frac{\sigma}{\sigma-1} \frac{w_i \lambda_i^{\beta-1}}{Z_i} \frac{P_j}{\tau_{ij}} \left(\frac{\sigma f_{xij}}{E_j} \right)^{1/(\sigma-1)} \right]^{1/(1-\alpha\beta+\alpha)}. \quad (10)$$

The productivity threshold is increasing in country i 's country-specific productivity-adjusted wage $\frac{w_i}{Z_i}$ and decreasing in country-specific quality λ_i . These results are both sensible. Since higher productivity adjusted wages raise marginal costs and prices all else equal, this raises the minimum idiosyncratic productivity level at which a firm could profitably export. On the other hand, higher country-specific quality lowers the quality-adjusted price all else equal and relaxes the productivity threshold for exporting since it raises demand for all country i firms.

In the export price data, we observe aggregate unit values rather than prices for individual firms. Thus, I construct aggregate unit values in the model to match the data. Aggregate exports from country i to country j are given by:

$$\begin{aligned} EX_{ij} &= \int_{z_{xij}}^{z_H} R_{xij}(z) N_i dG(z) \\ &= \int_{z_{xij}}^{z_H} \left(\frac{\tilde{p}_i(z) \tau_{ij}}{P_j} \right)^{1-\sigma} E_j N_i dG(z) \\ &= N_i \bar{V}_{ij} \left(\frac{\sigma}{\sigma-1} \frac{w_i \lambda_i^{\beta-1}}{Z_i} \right)^{1-\sigma} \tau_{ij}^{1-\sigma} P_j^{\sigma-1} E_j, \end{aligned} \quad (11)$$

where $\bar{V}_{ij} = \int_{z_{xij}}^{z_H} z^{(1-\alpha\beta+\alpha)(\sigma-1)} dG(z)$ is a country-pair specific term that quantifies the influence of the endogenous threshold on export volumes. Similarly I solve for the quantity of goods shipped from i to j as:

$$\begin{aligned} Q_{ij} &= \int_{z_{xij}}^{z_H} q_{xij}(z) N_i dG(z) \\ &= \int_{z_{xij}}^{z_H} (\tau_{ij} c_{ij}(z)) N_i dG(z) \\ &= N_i \bar{\bar{V}}_{ij} \left(\frac{\sigma}{\sigma-1} \frac{w_i \lambda_i^{\beta-1}}{Z_i} \right)^{-\sigma} \tau_{ij}^{1-\sigma} P_j^{\sigma-1} E_j \end{aligned} \quad (12)$$

where $\bar{\bar{V}}_{ij} = \int_{z_{xij}}^{z_H} z^{\sigma(1-\alpha\beta+\alpha)-\alpha} dG(z)$ quantifies the effect of endogenous thresholds on the quantity of exports.

The unit value export price for trade between i and j is then defined as $\bar{p}_{ij} = \frac{EX_{ij}}{Q_{ij}}$. To solve for this price, I evaluate $\bar{V}_{ij}$ and $\bar{\bar{V}}_{ij}$ using the Pareto distribution (6). Doing so yields:

$$\begin{aligned} \bar{V}_{ij} &= \frac{k}{\delta_1} \left(\frac{z_{xij}^{-\delta_1} - z_H^{-\delta_1}}{z_L^{-k} - z_H^{-k}} \right) \\ \bar{\bar{V}}_{ij} &= \frac{k}{\delta_2} \left(\frac{z_{xij}^{-\delta_2} - z_H^{-\delta_2}}{z_L^{-k} - z_H^{-k}} \right), \end{aligned}$$

where $\delta_1 = k - (\sigma - 1)(1 - \alpha\beta + \alpha)$ and $\delta_2 = k - \sigma(1 - \alpha\beta + \alpha) + \alpha$. I assume that δ_1 and δ_2 are both greater than zero to ensure the existence of a multifirm equilibrium. These technical restrictions require that the productivity distribution is not “too disperse” relative to consumer’s willingness to substitute across goods so as to ensure that consumption is spread across multiple goods in equilibrium.

Using these results, I can then solve for the unit value price:

$$\begin{aligned} \bar{p}_{xcd} &= p_i(z_H) V_{ij} \\ \text{with } V_{ij} &\equiv \frac{\bar{\bar{V}}_{ij}}{\bar{V}_{ij}} \equiv \left[\left(\frac{\delta_2}{\delta_1} \right) \left(\frac{\left(\frac{z_{xij}}{z_H} \right)^{-\delta_1} - 1}{\left(\frac{z_{xij}}{z_H} \right)^{-\delta_2} - 1} \right) \right]. \end{aligned} \quad (13)$$

The interpretation of this expression is the following: the average export price for country i exporting to j is proportional to the absolute price of the most productive firm ($p_i(z_H)$), where the proportional scaling factor V_{ij} depends on the productivity of the marginal exporter to market j with productivity z_{xij} relative to the most productive firm. Whether the average price

is higher or lower than $p_i(z_H)$ depends on the values of δ_1 versus δ_2 . Specifically, the sign of the slope of prices with respect to the productivity cutoff depends on the sign of $\delta_2 - \delta_1$.

Notice that $\delta_2 - \delta_1 = \alpha\beta - 1$, and recall that firm-level prices are decreasing in productivity if and only if $\alpha\beta < 1$. Naturally, this case implies that every firm charges prices that are equal to or higher than the most productive firm. As a result, the average export price to any given destination is higher than the price of the most productive firm. Hence, in this case $V_{ij} > 1$. In the opposite case ($\alpha\beta > 1$), prices are increasing in productivity and hence the average price is lower than the price of the most productive firm ($V_{ij} < 1$). Thus, not surprisingly, the export price schedule inherits the behavior of firm-level prices.

As with the firm-level price schedule, the flexibility built into (13) contrasts with the standard formulation of the model. Recall that in that version of the model, prices are unambiguously decreasing in firm-level productivity. Repeating the procedure to calculate unit values in that version of the model using the truncated Pareto distribution leads to a formula analogous to (13) in which the values of $\{\delta_1, \delta_2\}$ are replaced with $\delta_{M1} = k + 1 - \sigma$ and $\delta_{M2} = k - \sigma$. As a result, $\delta_{M2} - \delta_{M1} = -1$, and prices are unambiguously decreasing in the export threshold. In light of the results for the quality-choice model above, this discussion implies that if I find evidence that prices are decreasing in the export threshold, this does not allow me to discriminate between the quality-choice model and the standard Melitz model with homogeneous quality. On the other hand, if I find evidence that prices are increasing in the export threshold, I can both reject the standard formulation as well as reject the hypothesis that $\alpha\beta < 1$ in the endogenous quality formulation of the model.

2.4 Trade Volumes and Export Participation

As emphasized by Helpman, Melitz and Rubinstein (2007), the framework outlined above also yields predictions for export participation and export values. First, the model predicts that aggregate bilateral exports depend directly on the bilateral threshold. Thus, export thresholds are of interest not only in studying prices as in the previous section but also in understanding export values directly. Second, the model makes very specific predictions about when two countries should trade with one another. That is, unlike traditional variety-based trade models, this framework is able to make sense of the fact the vast majority of country pairs in fact do not trade with one another either in any given sector, or even in the aggregate. Using this aspect of the model, Helpman, Melitz and Rubinstein outline a method via which binary data on the existence of bilateral trade can be used to infer information about relative export thresholds. This section briefly exposit these features of the model.

Export thresholds influence aggregate exports by determining the number and identity of

exporting firms. To clarify this point, I rewrite the bilateral export equation (11) using the definition of $\bar{V}_{ij}$ to isolate variation in the number of exporting firms from variation in exports per firm:

$$EX_{ij} = \underbrace{N_i [1 - G(z_{xij})]}_{N_{xij}} \underbrace{\int_{z_{xij}}^{z_H} \left(\frac{\tilde{p}_i(z)\tau_{ij}}{P_j} \right)^{1-\sigma} E_j g(z|z > z_{xij}) dz}_{\text{exports per firm}}$$

This reformulation highlights that the number of exporting firms – denoted N_{xij} – is decreasing in the productivity threshold. Thus, holding exports per firm constant, increasing the export threshold depresses aggregate exports. Aggregate exports do not fall one for one with the number of firms exporting, however, because as the threshold rises the smallest exporters are the first to fall out of the foreign market. Thus, exports per remaining firm actually rises. To see this clearly, I evaluate the integral representation of exports per firm to show that the exports of the average firm are simply a scaled version of the exports of the most productive firm:

$$\frac{EX_{ij}}{N_{xij}} = \left[\frac{k}{\delta_1} \left(\frac{\left(\frac{z_{xij}}{z_H} \right)^{-\delta_1} - 1}{\left(\frac{z_{xij}}{z_H} \right)^{-k} - 1} \right) \right] \left(\frac{\tilde{p}_i(z_H)\tau_{ij}}{P_j} \right)^{1-\sigma} E_j,$$

with $\tilde{p}_i(z_H)$ defined as the quality-adjusted price of the most productive firm. Note here that average exports per firm vary across countries for two reasons. First, as it becomes more difficult to penetrate foreign markets (z_{xij} rises), the weakest firms are weeded out and the remaining firms are naturally larger, more productive, and sell larger volumes all else equal. Second, holding the export threshold constant, exports per firm will be higher when there are lower trade costs, the destination market is larger (higher E_j), or the destination market is less competitive (P_j is higher).

Putting the two margins together, aggregate exports across markets are always decreasing in the threshold. Simplifying the expression for exports leads to an expression that quantifies the net effect of variation in thresholds on aggregate export value:

$$EX_{ij} = N_i [(\tilde{p}_i(z_H))^{1-\sigma} \tau_{ij}^{1-\sigma} P_j^{\sigma-1} E_j] \left[\frac{k}{\delta_1} \left(\left(\frac{z_{xij}}{z_H} \right)^{-\delta_1} - 1 \right) \right]. \quad (14)$$

Exports are decreasing in the threshold because $\delta_1 > 0$. As emphasized by Helpman, Melitz, Rubinstein and detailed in the following section, this specification leads naturally to an augmented gravity equation that I use to estimate the net effect of endogenous cutoffs on exports.

Obviously, export productivity cutoffs are not directly observable in aggregate data. Help-

man, Melitz and Rubinstein also propose a procedure to infer these cutoffs from data on bilateral export participation that is applicable to the augmented model described above. Since firm productivity is drawn from a truncated Pareto distribution, quality-adjusted prices for each exporter are bounded below by the quality-adjusted price of the highest productivity firm. No firm from country i finds it profitable to export to destination j unless the most productive firm finds it profitable to serve that destination. Referring back to (8), the most productive firm serves destination j if $\frac{1}{\sigma}R_{xij}(z_H) \geq f_{xij}$. Then, I define χ_{ij} to be the ratio of the profits of the most productive firm to the fixed costs of exporting:

$$\chi_{ij} = \frac{\frac{1}{\sigma} \left(\frac{\tilde{p}_i(z_H)\tau_{ij}}{P_j} \right)^{1-\sigma} E_j}{f_{xij}}, \quad (15)$$

where I have evaluated the definition export revenue $R_{xij}(z)$ in equation (7) at z_H in the numerator. Then country i exports to j only if $\chi_{ij} \geq 1$. Based on this result, define a binary variable $T_{ij} = \mathbf{1}(\chi_{ij} > 1)$ that takes the value one if i exports to j and zero otherwise. Observation of this binary variable then reveals information about the ratio of profits to fixed costs of the most productive firm (χ_{ij}) in each sector. This turns out to be useful.

The key insight is that the relative productivity cutoff $\frac{z_{xij}}{z_H}$ is a monotonically decreasing function of χ_{ij} . To see this, note that the ratio of profits to fixed costs for the marginal exporter is exactly equal to one. Using this fact, it is straightforward to show that:

$$\frac{z_{xij}}{z_H} = \chi_{ij}^{-1/[(\sigma-1)(1-\alpha\beta+\alpha)]}. \quad (16)$$

Thus, the relative productivity cutoff for a firm in country i to earn profits selling in j is falling in the net profitability of the most productive firm of serving market j . Since the binary participation data contain information on χ_{ij} , they also reveal relative export thresholds across destinations that determine the behavior of prices and exports.

3 Empirical Procedure

In this section, I translate the framework outlined above into a set of conditional expectations for participation, exports, and export prices and discuss details about how I use these to estimate the model.

3.1 The Participation Equation

Drawing on the notation of the previous section, we observe a binary variable T_{ij} that takes the value one when the most productive firm in country i finds it profitable to serve market j : $T_{ij} = \mathbf{1}(\chi_{ij} > 1)$. The objective is then to translate this expression into an estimating equation. Start by taking logs of both sides of the definition of χ_{ij} in (15):

$$\log(\chi_{ij}) = \log(1/\sigma) + (1 - \sigma) \log(\tilde{p}_i(z_H)) + (1 - \sigma) \log(\tau_{ij}) + \log(P_j^{\sigma-1} E_j) - \log(f_{xij})$$

Following Helpman, Melitz and Rubinstein (2007), I parameterize the bilateral fixed and variable trade costs as follows:

$$\begin{aligned} (1 - \sigma) \log(\tau_{ij}) &= \rho D_{1ij} + \epsilon_{1ij} \\ -\log(f_{xij}) &= \vartheta_i + \vartheta_j + \gamma D_{2ij} + \epsilon_{2ij}, \end{aligned}$$

where D_{1ij} and D_{2ij} are multidimensional, possibly overlapping sets of observable proxies for bilateral fixed and variable trade costs (e.g., distance, common language, etc.), ϵ_{1ij} reflects random unobserved variation in variable trade costs, ϵ_{2ij} reflects random unobserved variation in fixed trade costs, and ϑ_i, ϑ_j are exporter and importer fixed effects. Substituting this parameterization back into the expression for $\log(\chi_{ij})$ yields a reduced form:

$$\log(\chi_{ij}) = \xi_0 + \xi_i + \xi_j + \rho D_{1ij} + \gamma D_{2ij} + \eta_{ij},$$

where I define $\eta_{ij} = \epsilon_{1ij} + \epsilon_{2ij}$ to be the composite measurement error on fixed and variable costs of trade, $\xi_0 = \log(1/\sigma)$ is a constant, $\xi_i = (1 - \sigma) \log(\tilde{p}_i(z_H)) + \vartheta_i$ is an exporter fixed effect composed of the price of the most productive firm and exporter-specific fixed costs, and $\beta_j = \log(P_j^{\sigma-1} E_j) + \vartheta_j$ is an importer fixed effect capturing characteristics of the importing market and importer-specific fixed costs.²⁰

Then substituting these expressions back, rewrite the expression for T_{ij} as:

$$\begin{aligned} T_{ij} &= \mathbf{1}(\log(\chi_{ij}) > 0) \\ &= \mathbf{1}(\eta_{ij} > -[\xi_0 + \xi_i + \xi_j + \rho D_{1ij} + \gamma D_{2ij}]). \end{aligned}$$

²⁰I define these parameters in a manner that is easy to interpret. One could equivalently re-define the parameters so that elements of $\tilde{p}_i(z_H)$ that do not vary across countries in the model (e.g., markups and $z_H^{1-\alpha\beta+\alpha}$) are contained in the constant term. There are a number of constants in this equation that are not separately identified.

With this in hand, the expectation of T_{ij} conditional on observables is:

$$\mathbf{E}[T_{ij}|\xi_i, \xi_j, D_{1ij}, D_{2ij}] = \mathbf{Pr}\{\eta_{ij} > -[\xi_0 + \xi_i + \xi_j + \rho D_{1ij} + \gamma D_{2ij}]\}$$

To operationalize this, I assume that the errors ϵ_{1ij} and ϵ_{2ij} are jointly distributed, mean zero normal random variables. Then η_{ij} is distributed $N(0, \sigma_\eta^2)$, where σ_η^2 is the variance of the composite error. Then it follows that:

$$\begin{aligned} \mathbf{E}[T_{ij}|\xi_i, \xi_j, D_{1ij}, D_{2ij}] &= \Phi(\xi_0^* + \xi_i^* + \xi_j^* + \rho^* D_{1ij} + \gamma^* D_{2ij}) \\ &= \Phi(X_{ij}\theta^*), \end{aligned} \tag{17}$$

where x^* indicates that x has been divided by σ_η so that η_{ij}^* has unit variance, and $X_{ij}\theta^* \equiv \xi_0^* + \xi_i^* + \xi_j^* + \rho^* D_{1ij} + \gamma^* D_{2ij}$ for notational convenience.

3.2 The Trade Equation

As discussed above, the model implies a gravity-style equation for bilateral export volumes. To illustrate this, I return to Equation (14) and take logs of both sides:

$$\begin{aligned} \log(EX_{ij}) &= \log(N_i) + (1 - \sigma) \log(\tilde{p}_i(z_H)) + (1 - \sigma) \log(\tau_{ij}) + \log(P_j^{\sigma-1} E_j) \\ &\quad + \log(k/\delta_1) + \log\left(\left(\frac{z_{xij}}{z_H}\right)^{-\delta_1} - 1\right). \end{aligned}$$

Then using the same parameterization of variable trade costs and redefining terms:

$$\log(EX_{ij}) = \psi_0 + \psi_i + \psi_j + \rho D_{1ij} + \log\left(\left(\frac{z_{xij}}{z_H}\right)^{-\delta_1} - 1\right) + \epsilon_{1ij},$$

where $\psi_0 = \log(k/\delta_1)$ is a constant, $\psi_i = \log(N_i) + (1 - \sigma) \log(\tilde{p}_i(z_H))$ is an exporter fixed effect, and $\psi_j = \log(P_j^{\sigma-1} E_j)$ is an importer fixed effect. Constructing moments using this equation then involves evaluating the expectation of this expression conditional on observables $\{\psi_i, \psi_j, D_{1ij}, X_{ij}\}$ and on observing trade between the pair ij (i.e., $T_{ij} = 1$). To minimize notational clutter, I write this conditional expectation as $\mathbf{E}[EX_{ij}|\cdot, T_{ij} = 1]$, where the dot notation stands for conditioning on observables $\{\psi_i, \psi_j, D_{1ij}, X_{ij}\}$.

To evaluate $\mathbf{E}[\epsilon_{1ij}|\cdot, T_{ij} = 1]$, note that the distributional assumptions made in the previous section imply that ϵ_{1ij} and η_{ij} are bivariate normal. This implies that the standard Heckman-

style correction is appropriate:

$$\begin{aligned}\mathbf{E}[\epsilon_{1ij}|\cdot, T_{ij} = 1] &= \mathbf{E}[\epsilon_{1ij}|\cdot, \eta_{ij}^* > -X_{ij}\theta^*] \\ &= v \frac{\phi(X_{ij}\theta^*)}{\Phi(X_{ij}\theta^*)}.\end{aligned}$$

where v is a selection parameter to be estimated and $\frac{\phi(X_{ij}\theta^*)}{\Phi(X_{ij}\theta^*)}$ is the inverse Mills ratio.

Evaluating the conditional expectation of the trade equation term involving the productivity threshold $\frac{z_{xij}}{z_H}$ requires linking the threshold to observables. To do so, I rewrite the threshold using equation (16) and the parameterization of χ_{ij} introduced in specifying the participation equation:

$$\begin{aligned}\frac{z_{xij}}{z_H} &= \chi_{ij}^{-1/[(\sigma-1)(1-\alpha\beta+\alpha)]} \\ &= [\exp((X_{ij}\theta^* + \eta_{ij}^*))]^{-\sigma_\eta/[(\sigma-1)(1-\alpha\beta+\alpha)]}\end{aligned}$$

Then insert this in the productivity threshold term to get:

$$\log\left(\left(\frac{z_{xij}}{z_H}\right)^{-\delta_1} - 1\right) = \log\left(\exp(\bar{\delta}_1(X_{ij}\theta^* + \eta_{ij}^*)) - 1\right),$$

where I define the new parameter $\bar{\delta}_1 = \frac{\sigma_\eta\delta_1}{(\sigma-1)(1-\alpha\beta+\alpha)}$. Using this substitution, I then use the assumption that η^* is normally distributed to construct the conditional expectation of the cutoff term as follows:

$$\begin{aligned}\mathbf{E}\left[\log\left(\left(\frac{z_{xij}}{z_H}\right)^{-\delta_1} - 1\right) \middle| \cdot, X_{ij}, T_{ij} = 1\right] \\ &= \int_{-X_{ij}\theta^*}^{\infty} \log\left(\exp(\bar{\delta}_1(X_{ij}\theta^* + \eta_{ij}^*)) - 1\right) d\Phi^T(\eta_{ij}^*) \\ &\equiv F(X_{ij}\theta^*, \bar{\delta}_1),\end{aligned}$$

where $\Phi^T(\eta_{ij}^*) = \frac{\phi(\eta_{ij}^*)}{1-\Phi(-X_{ij}\theta^*)}$ is the truncated distribution for η_{ij}^* .

With these inputs, the conditional expectation from which I generate moments for estimation is:

$$\mathbf{E}[EX_{ij}|\cdot, T_{ij} = 1] = \psi_0 + \psi_i + \psi_j + \rho D_{1ij} + F(X_{ij}\theta^*, \bar{\delta}_1) + v \frac{\phi(X_{ij}\theta^*)}{\Phi(X_{ij}\theta^*)}. \quad (18)$$

To be clear, the conditioning set here includes both the observables $\{\psi_0, \psi_i, \psi_j, D_{1ij}\}$ in the export equation as well as X_{ij} from the specification of the participation equation above. The expected value of exports depends on importer and exporter fixed effects, bilateral trade costs,

the level of the bilateral productivity threshold via $F(X_{ij}\theta^*, \bar{\delta}_1)$, and a term correction for sample selection.

3.3 The Price Equation

Estimation of the export price equation proceeds straightforwardly using the techniques developed in previous sections. To translate the deterministic specification of prices in the model into a stochastic specification for estimation, I assume (realistically) that prices are measured with multiplicative measurement error. Then I take logs of the export price equation (13) to obtain:

$$\log(\bar{p}_{xij}) = \log(\delta_2/\delta_1) + \log(p_i(z_H)) + \log\left(\frac{\left(\frac{z_{xij}}{z_H}\right)^{-\delta_1} - 1}{\left(\frac{z_{xij}}{z_H}\right)^{-\delta_2} - 1}\right) + \nu_{ij},$$

where ν_{ij} is mean-zero measurement error. Then, I substitute for the thresholds as in the previous section and construct $\mathbf{E}[\log(\bar{p}_{xij})|\cdot, T_{ij} = 1]$. In doing so, I deal with the function of the thresholds as in the previous section by substituting for the thresholds and then evaluating the conditional expectation using the truncated normal distribution $\Phi^T(\eta_{ij}^*)$. I denote this conditional expectation by $H(X_{ij}\theta^*; \bar{\delta}_1, \bar{\delta}_2)$, with $\bar{\delta}_1$ is defined as in the previous section and $\bar{\delta}_2 = \frac{\sigma_\eta \delta_2}{(\sigma-1)(1-\alpha\beta+\alpha)}$.

Further, note that $\log(p_i(z_H))$ is a constant for each exporting country and therefore can be absorbed by a exporter fixed effect. I then rewrite the conditional expectation of the price equation as:

$$\mathbf{E}[\log(\bar{p}_{xij})|\cdot, T_{ij} = 1] = \mu_0 + \mu_i + H(X_{ij}\theta^*; \bar{\delta}_1, \bar{\delta}_2), \quad (19)$$

where $\mu_0 = \log(\delta_2/\delta_1)$ is a constant and $\mu_i = \log(p_i(z_H))$ is an exporter fixed effect.

3.4 Estimation Details

In principle, it is possible to estimate all three structural equations simultaneously. In practice, this is computationally burdensome due to the high dimensionality of the parameter space. Therefore, I follow a two-step GMM procedure.²¹ In the first step, I use binary participation data to estimate the export participation equation (17) within each sector. With these estimates in hand, I generate values for the Probit index that are then used to construct the functions $F(X_{ij}\theta^*; \bar{\delta}_1)$, $H(X_{ij}\theta^*; \bar{\delta}_1, \bar{\delta}_2)$, and the inverse Mills ratio in expressions (18) and (19). For

²¹In unreported results, I have compared the results from the two-step procedure implemented in the main text to alternative estimates for selected sectors obtained by simultaneously estimating the three equations. The results are indistinguishable. This implies that the pattern of export participation contains all available information regarding the values of the productivity thresholds.

convenience, I rewrite the conditional expectations here as estimating equations:

$$\log(\bar{p}_{xij}) = \mu_0 + \mu_i + H(X_{ij}\hat{\theta}^*; \bar{\delta}_1, \bar{\delta}_2) + e_{1ij} \quad (20)$$

$$\log(EX_{ij}) = \psi_0 + \psi_i + \psi_j + \rho D_{1ij} + F(X_{ij}\hat{\theta}^*, \bar{\delta}_1) + v \frac{\phi(X_{ij}\hat{\theta}^*)}{\Phi(X_{ij}\hat{\theta}^*)} + e_{2ij}, \quad (21)$$

where I have substituted the first stage estimator of θ^* for the true value and have defined:

$$e_{1ij} \equiv \log(\bar{p}_{xij}) - \mathbf{E}[\log(\bar{p}_{xij})|\cdot, T_{ij} = 1]$$

$$e_{2ij} \equiv \log(EX_{ij}) - \mathbf{E}[\log(EX_{ij})|\cdot, T_{ij} = 1].$$

I estimate these two equations jointly using sectoral trade and prices by stacking moment conditions and imposing the cross equation restriction that the value of $\bar{\delta}_1$ is identical across the two equations. I focus on a small set of straightforward moments to estimate these equations, all built on the orthogonality between the errors and the regressors.²² As implemented, the problem is exactly identified and hence moments are equally weighted.²³ In light of the fact that I use a two-stage estimation procedure, I construct standard errors for the second stage estimates using the two-step GMM procedure laid out in Newey and McFadden (1994).²⁴

In specifying the trade equation above, there are two non-linear functions of the estimated first stage Probit index: $F(X_{ij}\hat{\theta}^*, \bar{\delta}_1)$ and the inverse Mills ratio. To ensure that identification in the trade equation does not rest on functional form alone requires that there is a variable among the conditioning set that influences the probability of observing exports but does not directly affect the level of exports. On theoretical grounds, measures of fixed trade costs satisfy the necessary exclusion restriction. Helpman, Melitz, and Rubinstein (2007) employ proxies for such costs using data on general firm entry costs and common religion as excluded variables when working with aggregate data.²⁵ In the sector-level data I use, neither of these variables is strongly or robustly correlated enough with the probability of trading to use in the estimation.

²²The only modestly non-standard conditions worth mentioning are: $\mathbf{E}[e_{1ij}(X_{ij}\hat{\theta}^*)] = 0$ and $\mathbf{E}[e_{2ij}(X_{ij}\hat{\theta}^*)] = 0$. These are non-standard only in the sense that they are constructed such that the composite $X_{ij}\hat{\theta}^*$ is orthogonal to the error rather than the individual elements of X_{ij} . One could also use these individual elements, though in practice the composite contains much more useful identifying variation.

²³To reduce the computational burden in the present scheme, I collapse the set of moments by “partialing out” the linear portion of the two equations, solve for the parameters $\{\bar{\delta}_1, \bar{\delta}_2\}$ using the collapsed moments, and then return to the full set of moments to compute the fixed effects.

²⁴The two-step procedure stacks the moments from the first and second stages into a single joint vector of moments and computes the asymptotic variance of this full set of moments. Because the two-step procedure yields consistent estimates, this variance may be evaluated using the two-step estimates. Work in progress considers bootstrapped standard errors as a robustness check on this procedure.

²⁵Manova (2006) uses a dummy variable coding whether a country is an island as an excluded variable.

Instead, I propose using lagged participation in bilateral trade as a variable that predicts selection, but does not have a direct effect on export volumes controlling for its indirect influence via the productivity threshold and the inverse Mills ratio. While there is much churning in trading relationships at the disaggregate level from year to year, participation in bilateral trade with a given partner in the past is a strong predictor of whether two countries trade today. There are a number of a priori grounds on which lagged participation seems well suited to be a proxy for fixed costs of trading. To the extent that some of the fixed export cost is sunk at the firm level, payment of this cost in the past makes it more likely firms will find it profitable in the present to export to a given country.²⁶ Abstracting beyond the level of the individual firm, initiating trade may entail establishment of sector-wide contacts and relationships, information sharing mechanisms, and distribution networks whose cost does not vary with the actual volume of goods traded.²⁷ These types of links are further likely to persist through time. With this motivation, I construct a measure of how frequently two countries have traded in the past to use in estimating the participation equation.

In thinking about identification, it is helpful to be clear about where the exclusion restriction bites in terms of identifying the model and hence what failure of this assumption would imply for interpretation of the empirical work. A subtle aspect of the empirical model is that the exclusion restriction is important for identifying the levels of $\{\bar{\delta}_1, \bar{\delta}_2\}$, but has virtually no effect on $\bar{\delta}_2 - \bar{\delta}_1$. This is because the price equation tightly identifies the difference $\bar{\delta}_2 - \bar{\delta}_1$ – loosely speaking, the slope of prices with respect to the productivity thresholds – but does not tightly identify the level of these parameters. As such, the trade equation is nearly exclusively responsible for governing the level of the parameters. Because the exclusion restriction is necessary to identify the trade equation, failure of that restriction would influence the level of the estimates for $\{\bar{\delta}_1, \bar{\delta}_2\}$, but has almost no effect on the difference $\bar{\delta}_2 - \bar{\delta}_1$. Since most of the empirical work below is focused on interpreting this difference, this fact is reassuring.

3.5 Interpreting the Estimates

Before moving on to the actual estimation, let us pause to discuss how the estimated parameters can be interpreted and combined to draw inferences about the underlying structure of export selection and trade patterns.

²⁶Roberts and Tybout (1997), for example, find that prior export experience increases the probability of exporting in the present by approximately 60 percentage points for individual firms in Colombia.

²⁷This reasoning suggests that some observable variables, such as common language or colonial history, might also satisfy the necessary exclusion restriction. For example, Rauch (1999) argues that common language and colonial ties influence whether two countries trade in non-standardized, heterogeneous goods that require intensive information sharing. In on-going work, I am re-estimating the model using these variables in place of lagged participation as excluded variables. Preliminary unreported results suggest the results are robust.

First, we can use model estimates to study the role of endogenous non-tradability in explaining variation in prices by looking at estimated values of $\{\bar{\delta}_1, \bar{\delta}_2\}$. Recalling previous results, the price schedule slopes downward with respect to the productivity threshold only if $\alpha\beta < 1$. Under restrictions imposed by the model, we can identify whether this is in fact true from the estimated parameters. To see this, take the difference between the coefficients:

$$\begin{aligned}\bar{\delta}_2 - \bar{\delta}_1 &= \frac{\sigma_\eta}{(\sigma - 1)(1 - \alpha\beta + \alpha)} (\delta_2 - \delta_1) \\ &= \frac{\sigma_\eta}{(\sigma - 1)(1 - \alpha\beta + \alpha)} (\alpha\beta - 1).\end{aligned}\tag{22}$$

The sign of this difference is a direct indication as to whether the price schedule is increasing or decreasing in the productivity threshold. If $\bar{\delta}_2 - \bar{\delta}_1 > 0$, then export prices are increasing in the threshold. Furthermore, this difference directly reveals whether $\alpha\beta > 1$, since $(1 - \alpha\beta + \alpha) > 0$ in the model.²⁸ As a result, this difference will serve as a focal point in the discussion of the empirical results.

Additional results regarding the relative importance of cross-country quality and variety versus price differences in explaining trade patterns can be obtained by exploiting the structure of the model. First, note that by the definition of the parameters, $\exp(\mu_0 + \mu_i) = \frac{\delta_2}{\delta_1} p_i(z_H)$. Defining $M_i = \exp(\mu_0 + \mu_i)$, the ratio $\frac{M_i}{M_j} = \frac{p_i(z_H)}{p_j(z_H)}$ then allows us to recover the relative prices of the most productive exporting firm across countries. Similarly, note that by definition:

$$\begin{aligned}\exp(\psi_0 + \psi_i) &= \frac{kN_i}{\delta_1} (\tilde{p}_i(z_H))^{1-\sigma} \\ &= \frac{k}{\delta_1} [N_i(\lambda_i(z_H))^{\sigma-1}] (p_i(z_H))^{1-\sigma}\end{aligned}$$

Then, define $\Psi_i = \exp(\psi_0 + \psi_i)$ and it follows that:

$$\frac{\Psi_i}{\Psi_j} = \left(\frac{N_i(\lambda_i(z_H))^{\sigma-1}}{N_j(\lambda_j(z_H))^{\sigma-1}} \right) \left(\frac{M_i}{M_j} \right)^{1-\sigma}.\tag{23}$$

Thus, with an assumption about the value of σ we can back out $\left(\frac{N_i(\lambda_i(z_H))^{\sigma-1}}{N_j(\lambda_j(z_H))^{\sigma-1}} \right)$, where $N_i(\lambda_i(z_H))^{\sigma-1}$ is a composite index of product variety and quality for each country.

Decomposing the exporter fixed effect in this manner sheds light on the role of quality and variety in explaining differences in aggregate exports across countries. In economic terms, higher country-specific quality (λ_i) and total variety (N_i) shift the aggregate export demand schedule

²⁸To recap the argument, $(1 - \alpha\beta + \alpha) > 0$ means that quality adjusted prices are decreasing in idiosyncratic productivity z . This restriction is implied by parameter restrictions necessary to ensure the existence of an interior maximum in the firm's quality choice problem.

for country i outward relative to other exporters. In contrast, differences in prices across countries move exporters along their respective aggregate export demand curves. Decomposing the fixed effect in this manner then allows us to quantify the extent to which differences in aggregate exports are associated with differences in the location of aggregate demand curves across countries versus differences in the countries location along their respective demand curves.²⁹

4 Estimation Results

This section implements the estimation framework outlined in previous sections. We begin with a discussion of the data, and then proceed to the results.

4.1 Data

The main body of data on disaggregated world trade has been compiled by Robert Feenstra and Robert Lipsey and is available from the NBER and the Center for International Data at UC Davis.³⁰ Because data for the United States in the Feenstra-Lipsey data are somewhat less reliable and comprehensive than U.S.-sourced data, I also use United States trade value and quantity data compiled by Robert Feenstra, John Romalis, and Peter Schott.³¹ While these data are available at the 4-digit level of disaggregation and beyond, I aggregate reported exports and quantities into 3-digit sectors.³² Furthermore, I discard non-manufacturing trade on the grounds that the Melitz monopolistic competition model ought to be best suited to understanding trade in differentiated manufactures. After dropping several sectors due to missing data, I am left with data on 141 3-digit sectors spanning SITC categories 5-8.³³ From these data on values and quantities, I construct unit values for each exporter by sector and destination market. Details regarding data preparation are discussed in Appendix B.

In addition to these trade data, I use data on standard proxies for bilateral trade costs as in Helpman, Melitz, and Rubinstein (2007). The data include physical impediments to trade including measures of distance between capital cities, and dummies for whether two countries share a border, whether one partner is landlocked, and whether one partner is an island. Further,

²⁹Of course, aggregate exports are also influenced by aggregate destination size, bilateral trade costs, and export productivity thresholds. Decomposing the exporter fixed effect is like performing an experiment in which we look at export variation across countries holding all these other factors constant.

³⁰See Feenstra, Lipsey, Deng, Ma and Mo (2005) for details on the construction of this data.

³¹See Feenstra, Romalis and Schott (2002) for details on the construction of the U.S. data.

³²Trade is quite sparse at the disaggregated level for most countries, and therefore some aggregation is helpful to thicken the density of the bilateral trade matrix for estimation purposes.

³³For reference, the 1-digit category headings are as follows: 5-“Chemicals and related products”; 6-“Manufactured goods, classified chiefly by material”; 7-“Machinery and transport equipment”; 8-“Miscellaneous manufactured articles”.

the data include measures of cultural and historical ties that may facilitate or impede trade, including a measure of the commonality of religious affiliation, and dummy variables for past colonial relationship, common legal origin, and common language.³⁴ As mentioned above, I also construct an additional variable based on previous trading experience to use in estimating the participation equation. In the year 2000 base estimation, I construct a variable for each pair equal to the fraction of years between 1985-1995 in which the two countries engaged in trade.³⁵ In analyzing prices and thresholds, I also employ data on real GDP per capita and population across countries from the Penn World Tables (Version 6.2).

The final estimation sample includes the 125 countries listed in Table 1 for which I have data on trade, prices, and trade costs in the year 2000. The exact composition and size of the estimation sample varies from sector to sector depending on which countries engage in trade in a given sector.

4.2 Estimating the Participation Equation

In Table 2, I present representative results from the first stage Probit estimation for eight sectors. I naturally omit estimates for the large number of exporter and importer fixed effects from the table. Suffice it to say that the vast majority of these coefficients are significantly different from zero and that they account for a large share of the overall variation in the data. The remaining variables in the Probit specification are proxies for fixed and variable costs of trade – D_{1ij} and D_{2ij} in the nomenclature of (17). In practice, I allow all trade cost proxies, with the exception of lagged participation in trade, to appear in both D_{1ij} and D_{2ij} . As a result, the estimated coefficients on these variables in the participation equation measure the net effect of these variables operating via both fixed and variable costs on the probability of bilateral trade.

The probability of trade between two countries is strongly and robustly decreasing in the distance between them. To the extent that distance is correlated with bilateral fixed and/or variable trade costs, the negative coefficient is consistent with theory since higher costs of serving foreign markets make it less likely that the most productive firm will find it profitable to export to that market. The probability of trade also tends to increase if the countries share a common border, common language, or common legal system. Interpreted via the theory, these coefficients are also sensible. A common border is likely to be associated with lower variable and/or fixed costs. Further, sharing a common language or legal system could plausibly lower fixed costs of establishing a trading relationship.³⁶ The consequences of being an island, being landlocked, or

³⁴See Appendix B for details.

³⁵In ongoing work, I am studying the robustness of the results to alternative specifications of this lagged participation variable as well as experimenting with alternative excluded variables and fixed cost proxies.

³⁶For example, sharing a common language or legal system could lower the costs of making contacts and establishing a distribution network in foreign markets. The link between common language and common legal

of sharing common colonial history and religion are more mixed. It is not surprising that some estimates are unstable across sectors, since the country composition of the estimation sample varies substantially across sectors simply because many countries participate only in a subset of sectors.³⁷ The probability of engaging in trade today is also positively related to the average propensity of the two countries to have traded in the past. As discussed above, the strong and robust nature of this relationship is an important fact that provides identification in estimating the trade equation.

Before proceeding to the second step of the estimation, I pause to assess the plausibility of the estimates. From a mechanical perspective, the predicted probability of trade between two countries can be high when either the exporter fixed effect is large, the importer fixed effect is large, or bilateral trade costs (measured via proxies) are low. Conditional on participation in trade in a given sector, the exporter fixed effect is high when a country exports to many destinations and the importer fixed effect is high when a country imports from many destinations.³⁸ On the import side, the aggregate market size of the importer is likely to be a strong determinant of demand in any given sector. High demand in turn leads a large number of countries to serve the market and raises the predicted probability of any given source country serving the market. To check whether the estimates are consistent with this mechanism, I construct a trade-weighted average of the predicted Probit index ($X_{ij}\hat{\theta}^*$) for each importing country j in four random sectors. In Figure 1, I plot the resulting aggregate index against aggregate real GDP of the importer. The predicted probability of trade is clearly increasing in the aggregate size of the destination market in all four sectors. Since the predicted probability of trade is increasing in the Probit index, large destination markets will have a higher probability of importing on average from any given partner. In turn, the predicted productivity thresholds for serving those large markets will be lower on average.

As an alternative credibility check, I rank U.S. export destinations according to the ease of foreign market access on average. Similar to the previous calculation, I construct an aggregate index for each destination market that equals the trade-weighted average of the predicted Probit index across all sectors. I then rank destinations according to the probability of observing trade, with low numbered rankings indicating a high probability of trade and hence a low threshold

system on variable trade costs is less obvious.

³⁷The median number of exporters in a sector is 75, and 90% of the sectors have 60 or more exporters. The maximum is 99 and the minimum is 33. The number of importers per sector is somewhat larger. The median number of importers is 105, and 90% of the sectors have more than 95 importers.

³⁸In terms of economic fundamentals, comparative advantage based on technology or endowments is likely to be an important determinant of how many destinations a given exporter serves. Bernard, Redding, Schott (2007) study the theoretical properties of the Melitz model in an environment in which comparative advantage influences the sectoral composition of production and exports. To my knowledge, the empirical validity of this prediction has not been explored empirically at the sectoral level for a wide range of countries. This is a natural extension of the empirical work presented here.

for exporting to that market. Table 3 contains the resulting ranking. The results are mostly consistent with intuition and the model. Mexico is ranked as the easiest market for U.S. firms to enter, and the United Kingdom and other European markets dominate the top portion of the list. The bottom of the list is populated by predominantly low income countries and small markets. Overall, the level of the threshold across markets appears to convey sensible information about how hard it may be for U.S. firms to penetrate foreign markets.³⁹

A further interesting fact about average propensities to trade is that the predicted probability of exporting is generally higher for large and wealthy exporters. To document this, I construct an aggregate trade-weighted predicted Probit index for each exporter in the same four sectors as above and plot the result against real GDP per capita of the exporter in Figure 2. The figures clearly indicate that poorer countries tend to have lower indices and hence predicted probabilities of exporting on average. As a result, they will also have higher export thresholds on average. Though the data do not permit me to identify the origin of this statistical relationship, the theoretical model suggests that lower income countries might face higher thresholds due to higher fixed and/or variable costs of accessing foreign markets. Alternatively, lower average product quality in low income countries could also explain this result. For the present paper, the important consequence of this result is that differences in average export thresholds across countries could result in price differences across countries. I return to this point below.

4.3 Estimating the Trade and Price Equations

With the first stage estimates in hand, I turn to discussing estimates from the trade and participation equations. Motivated by the theoretical development above, I focus on documenting three facts. First, in the typical sector, prices are increasing in the export productivity threshold of serving foreign markets. This amounts to a rejection of the price predictions of the benchmark Melitz model in which prices are uniformly decreasing in the export productivity threshold. The results are consistent with the endogenous quality version of the model outlined in Section 1. Furthermore, the pattern of slope estimates across sectors provides supportive evidence that differences in incentives for quality upgrading across sectors can explain differences in estimated slopes. Second, variation in productivity thresholds plays only a small role in explaining variation in prices either within exporters across destinations or across countries on average. Instead,

³⁹Ranking countries on a sector-by-sector basis provides an alternative to this aggregate ranking and yields generally similar results. Moreover, it does not suffer from the problem that aggregate country ranks are distorted by the fact that the U.S. exports to a different set of countries in each sector and exports in only a small number of categories to some countries. The aggregate rankings may therefore be misleading when they are based on a small subset of goods. As such, the literal ranking should be interpreted carefully as it provides a possibly distorted picture of typical rankings within specific sectors and may fail to rank countries with which the U.S. does not trade extensively (e.g., Iran) inappropriately.

exporter-specific factors (common to all destination markets for a given exporter) explain a sizable portion of the overall variation. Third, variation in export thresholds appears to play a large role in accounting for the volume of trade at the sector level.

4.3.1 Slope of the Price Schedule

The relationship between export prices and productivity thresholds is controlled by $\bar{\delta}_2 - \bar{\delta}_1$. As discussed above, export prices are increasing in the productivity threshold when $\bar{\delta}_2 - \bar{\delta}_1 > 0$ and decreasing otherwise. Tables 4 and 5 contain estimates and standard errors for $\bar{\delta}_1$, $\bar{\delta}_2$ and the difference $\bar{\delta}_2 - \bar{\delta}_1$.⁴⁰

The point estimates of $\bar{\delta}_2 - \bar{\delta}_1$ indicate that the price schedule is positively sloped in 87 sectors, and significantly positive (at the 10% level) in 68 sectors. The remaining sectors have a negative slope, and this slope is significantly negative in 30 sectors. Thus, positive price slopes are in general more prevalent in the data, and only a fifth of the sectors can be said with any certainty to have a negative slope.

These results strongly contradict the basic prediction of the Melitz model that export prices for a given exporter should be decreasing in the productivity threshold across destination markets. In contrast, the quality-choice augmented model provides an explanation for the prevalence of positive slopes. Interpreted via that model, the data suggest that quality is typically strongly increasing in productivity. That is, quality is both on average positively associated with the physical productivity of the firm and that incentives to upgrade quality for high productivity firms are typically strong enough to lead them to charge higher absolute prices.

To study the pattern of estimates across sectors, I plot $\bar{\delta}_2 - \bar{\delta}_1$ by sector in Figure 3. In the figure, solid points indicate that the point estimate for the slope in that sector is significantly positive or negative at the 10% level or better in a test against the one-sided alternative. Several features of the figure are worth noting. First, if the benchmark Melitz model provided accurate price predictions, then all the point estimates should lie below zero on the graph. Obviously, that is not the case. Most of the significant estimates are positive and even most insignificant estimates are either positive or close to zero. Second, the estimates tend to cluster in two main groups, indicated in the graph by the vertical line superimposed at SITC category 756. To the left of this partition, the point estimates are nearly all greater than zero. To the right, they are predominantly less than zero. Moreover, nearly all the significant negative estimates are clustered in specific groups of sectors. The significant negative estimates are centered almost exclusively in categories 751-778 and 831-881. The first grouping (751-778) includes electronics

⁴⁰Careful inspection of the table indicates that estimates of the level of these parameters separately are somewhat less precise than estimates of the difference between the two parameters. This is because estimates of $\bar{\delta}_1$ and $\bar{\delta}_2$ are very highly correlated. In most sectors, they move together nearly one-for-one. As a result, the slope of the price equation is tightly identified even when the absolute levels of the separate parameters are not.

and appliances, such as typewriters, television receivers, car radios, and household laundry equipment. The second grouping (831-881) is predominantly apparel and footwear, with several additional categories for other electronics including cameras and gas/liquid/electricity meters. In contrast, in SITC category 5 – comprised entirely of manufactured chemicals – 17 of 23 point estimates are significant and positive. In SITC category 6 – comprised of a variety of primarily industrial-use manufactures classified by material (including iron and steel, rubber, paper, etc.) – 32 of 49 point estimates are significant and positive.⁴¹

The fact that positive and negative point estimates are tightly clustered into clearly identifiable product groups suggests that the pattern of sectoral heterogeneity is informative about the mechanism at work in both the data and model. In the quality choice model, we should observe negative point estimates if incentives to upgrade quality are weak. Weak incentives can result either because upgrading quality has minimal demand-side benefits, or because technological opportunities to upgrade quality are limited. In the model, benefits of upgrading quality are weak when consumers are unresponsive to changes in quality adjusted prices (σ is small). Limited technological opportunities for upgrading can be thought of as a situation in which the cost of upgrading quality increases sharply in the level of quality (ϕ is large). Both these scenarios lead to relatively low equilibrium quality dispersion within a sector and allow the direct marginal cost benefits of high productivity to dominate the behavior of prices.

If the quality upgrading channel is to explain the data, then electronics and apparel and footwear should have relative low quality dispersion relative to chemical manufacturing, for example. In fact, Khandelwal (2007) argues that apparel/footwear and electronics are sectors characterized by relatively small degree of vertical quality differentiation across countries, whereas quality differences in chemicals are large. To the extent that international quality dispersion proxies for the technological and/or demand-related features of different sectors that carry over to producers within countries, then this evidence suggests that quality upgrading may account for a large portion of the sectoral heterogeneity in point estimates.

Existing Evidence on Firm Level Prices While this paper uses aggregate data to make inferences about the relationship between quality and productivity, quality upgrading also produces detectable patterns in firm-level data.⁴² There are at least two pieces of microeconomic evidence that would provide evidence in favor of the quality hypothesis. First, the endogenous quality model with strong quality upgrading ($\alpha\beta > 1$) implies that exporting firms should charge higher prices on average than non-exporting firms. In contrast, both the standard model and the

⁴¹Counting positive point estimates without regard to statistical significance, 19 of 23 point estimates are positive in category 5, and 37 of 49 in category 6.

⁴²Though I use the term “firm-level” to describe the data, it is perhaps more appropriate to call this data “plant-level” data since manufacturing census data is collected on a plant-by-plant rather than firm-by-firm basis.

endogenous quality model with weak quality upgrading ($\alpha\beta < 1$) would predict that exporting firms charge lower prices on average. Second, the model also predicts that firm level prices in strong quality upgrading sectors should be increasing in firm size (revenue). As a corollary, since Eaton, Kortum, and Kramarz (2007) report that larger firms serve more foreign markets than smaller firms, the endogenous quality model with $\alpha\beta > 1$ also predicts that prices should be increasing in the number of foreign markets that a firm serves.

Although few papers have examined prices in census-style data, several interesting examples do exist that shed light of the relationship between productivity, size, and unit prices. One is a recent paper by Hallak and Sivadasan (2006). Using data from the Indian Annual Survey of Industries for 1997-1998 that includes price data, Hallak and Sivadasan find both that exporters within industries charge higher prices than non-exporters on average and that firm-level unit prices are increasing in firm size.⁴³ This provides prima facie evidence that the endogenous quality-augmented Melitz model could provide an explanation for firm level price facts. Whether these results are robust and hold outside the Indian context is an open question.

Unfortunately, evidence for the United States on the relationship between plant level prices and plant size and/or export status is limited. Even the few studies that do exist do not address the questions raised in this paper directly because they focus exclusively on homogeneous quality industries. Nonetheless, they do provide a useful benchmark in the sense that the model in this paper predicts that prices should be decreasing in firm size and physical productivity in these homogeneous quality industries. And indeed, the data seem to confirm this prediction. Roberts and Supina (1996, 2000) find that for a selection of homogeneous industries prices are typically decreasing in firm size, with small producers charging prices up to 20% higher than the mean within sectors and large producers charging prices around 10% lower than the mean. Looking at similar industries, Foster, Haltiwanger and Syverson (forthcoming) also report that plant-level prices are typically falling in measured plant level physical productivity. These results are comforting to the extent that they indicate that the relationship between prices and plant size in homogeneous quality industries conforms to theory. This strengthens the case that the price behavior I uncover using aggregate export prices is inconsistent with the behavior of prices in homogeneous quality industries. Extending the micro-analysis in these papers to industries in which product quality varies across plants would be a useful objective for future research. Linking this type of data to plant-level export behavior would be even better, as it would provide direct evidence on the role of quality heterogeneity in understanding export behavior and export prices.

⁴³These results are based on within industry variation. This means that fixed characteristics common to all firms in an industry that affect average prices, export behavior, and/or size of firms in one industry versus another are not driving these results.

One paper that comes close to this ideal for non-U.S. data is Aw, Batra and Roberts (2001). Aw, Batra and Roberts use data on electronics producers from the Taiwanese manufacturing census to construct average unit values for exports relative to goods sold domestically for specific products.⁴⁴ They find that there are large differences in average export unit values relative to average unit values for domestic sales within defined product groups. For the majority of products, the export unit value is lower than the domestic unit value. For example, in 1991, the average price for exported color televisions was equal to 60% of that for televisions sold in the domestic market. Similarly, exported floppy disk drives had an average price equal to 88% of those sold domestically. These results are consistent with my estimates for consumer electronics, which imply exporters should charge lower prices than non-exporters.⁴⁵ Further, using prices of firms that both export and sell domestically, Aw, Batra and Roberts find that individual firms do not systematically price discriminate between the two markets. Thus, the unit value price differential between domestic and export markets is not due to firms setting different prices in the two markets. Rather, the price gap appears to arise from differences in the composition of firms operating in each market.⁴⁶ This is precisely the mechanism identified in both the benchmark Melitz model and my quality-augmented adaptation, where selection occurs based on a variable – productivity – that is correlated with prices. Moreover, this data provides further support that the estimates I obtain for prices in electronics are consistent with micro-level facts. Again, whether these results from Taiwan carry over to other countries and products is an open question.

Robustness of Slope Estimates Before proceeding, I perform some additional analysis to confirm that the estimates of the price equation slope are not artifacts of assumptions I have made in the estimation process, specifically regarding functional form and the exclusion restriction used to estimate the trade equation along with the price equation. To do so, I run a sequence of linear regressions within each sector to sign the correlation of prices with the productivity thresholds. As in the general model, special attention must be paid to both the fact that the thresholds are unobserved and prices are observed only if trade takes place. To be

⁴⁴Broad product categories include data storage and processing (e.g., disk drives, monitors, keyboards, etc.), consumer electronics and parts (e.g., televisions, radios, television tubes, capacitors, etc.), and communication equipment (e.g., telephones).

⁴⁵To be fair, some sectors have higher reported domestic aggregate unit values than export unit values. However, the majority of goods – 16 of 26 in 1991 – do have lower unit values. It is difficult to know how these price differences in this micro data would aggregate to the SITC categories that I use.

⁴⁶To be clear, Aw, Batra, and Roberts use data on two years – 1986 and 1991. In the first year, they find evidence of price discrimination between domestic and foreign markets in sectors subject to strong import restrictions. In contrast, when these restrictions are removed by 1991, the evidence of price discrimination disappears. These post-liberalization price differences provide the most compelling evidence that differences in the composition of firms serving the domestic and export markets are driving unit value price differences.

clear, I specify the conditional expectation of log export prices as:

$$\mathbf{E}[\log(\bar{p}_{ij})|\cdot, T_{ij} = 1] = \mu_i + \varsigma \mathbf{E} \left[\log \left(\frac{z_{xij}}{z_H} \right) \middle| \cdot, T_{ij} = 1 \right], \quad (24)$$

where the dot notation indicates conditioning on observables $\{X_{ij}, \mu_i\}$. Then I substitute for $\frac{z_{xij}}{z_H}$, construct the appropriate conditional expectation as in the general model, and estimate the resulting equation to sign the partial correlation coefficient ς . I start by signing ς in the full data set, and then repeat the exercise using only U.S. export prices in the 118 sectors that the US exports to 20 or more partners.⁴⁷ The results are tabulated in Table 5 along with the tabulation of slope estimates from the non-linear specification discussed above. The results confirm the incidence of positive and negative slopes documented previously. In the full data set, 60% of the price equation slopes are positive (with 45% significant and positive) and the remaining slopes are negative (with 28% significant and negative). For the US data, even a greater share of point estimates are positive (74%), though less are statistically significant. The reduced statistical significance is likely due to the much smaller sample sizes in the US data. Moreover, only 2% of the estimates correlations for the US are negative and significant.

To see these raw correlations in the data, I turn to export data for the U.K. In Figure 4, I plot log export prices in four sectors for the U.K. against the rank of the destination market in the U.K.'s export hierarchy in that sector (with 1 indicating the easiest foreign market to enter). As is evident, three of the four sectors here have positive and one has a negative slope. To the naked eye, it also appears that there is a substantial amount of price variation within these sectors not explained by productivity thresholds. I return to this issue in the next section.

4.3.2 Accounting for Prices and Trade

Given that prices and trade volumes vary across countries, an important question is whether differences in productivity thresholds explain this variation or whether other factors are at work. I thus turn to a discussion of accounting. In general, the model accounts for a substantial amount of the overall variation in prices and trade volumes. Figure 6 plots the fraction of the variance in log exports within each sector that is accounted for by the model. In general, the model captures upwards of 80% of the overall variance in most sectors. As for prices, Figure 5 plots the fraction of the variance in prices explained by the model by sector.⁴⁸ Although the fit of the

⁴⁷As in estimation of the general model, I include a U.S. importer dummy in addition to exporter fixed effects when using the full data set to account for differences in units between the U.S. and rest of the world.

⁴⁸This figure and the related calculations exclude the United States. Because the US data has different units, this introduces artificial volatility into raw prices due to level differences between the US and rest of the world. These are picked up in US exporter and importer fixed effects in the estimation. Including the US in these variance calculations would therefore overstate the ability of the model to match overall variation.

model fluctuates from sector to sector, on average the model is able to account for almost half of the overall variance in prices.

The model also does quite well in accounting for the stylized fact documented by Schott (2004) that the price at which the U.S. imports from different source countries within sectors is strongly correlated with GDP per capita of the exporting country. To replicate Schott's results, I regress the log U.S. import price in each sector on the GDP per capita of the exporter. To compare this to the model, I perform an identical regression with predicted prices in place of actual prices. The resulting coefficients for the 102 3-digit sectors in which the U.S. imports from 20 or more partners are plotted against one another in Figure 7. In general, these coefficients match up very closely indicating that the model is able to replicate the strong relationship between log income and export prices that Schott documents.

The natural question to ask is whether the ability of the model to match the price facts derives from variation in the productivity thresholds or country-specific factors. The answer is that country-specific factors play the dominant role in explaining overall price variation. To illustrate this fact, I decompose the variance of predicted prices in the model by calculating the variances and covariance of the exporter fixed effect and the threshold term. Figure 8 plots the results as a share of the total variance of predicted prices. As the figure indicates, the ratio of the variance in the exporter fixed effect to total variance in predicted prices is near or even exceeds one in many sectors. On the other hand, the ratio of the variance of the cutoff term to total variance is low in most sectors.⁴⁹ Moreover, the role for cutoffs in explaining overall variation in prices is diminished by the fact that the threshold term covaries negatively with the exporter fixed effect. This negative covariance arises due to the fact that poor (rich) countries have high (low) export thresholds on average, a fact I documented in Section 3.2, as well as low (high) exporter fixed effects. That is, poor countries both have low average export prices and high export thresholds. When the price schedule slopes up in the threshold, this means that there will be a negative covariance between the exporter fixed effect and the threshold term. In contrast, in sectors where the price schedule slopes down, there will be a positive covariance and a somewhat larger overall role for threshold variation in explaining prices.

Returning to Schott's stylized facts, this discussion naturally leads to the conclusion that differences in country-specific unit costs, rather than differences in productivity thresholds across countries, explain the strong correlation between prices and source-country income in US import prices. To illustrate this, Figure 9 plots observed prices, predicted prices, the estimated exporter price fixed effect, and the predicted value of the threshold term in the price equation against exporter GDP per capita for SITC 583 (Polymerization Products) in which prices are increasing

⁴⁹The fact that the variance of the cutoff term is near zero in some sectors is obviously a reflection of the fact that the estimated slope of the price equation is near zero in those sectors.

in the export productivity threshold for exporting. Figure 10 does the same for SITC 842 (Men's Outerwear) in which prices are decreasing in the thresholds. In both figures, the fact that prices are increasing in exporter GDP per capita is evident in the upper left hand graph. The upper right graph replaces actual prices with predicted prices to illustrate that the model does a good job matching this fact. Comparing this graph to the lower left hand graph of exporter fixed effects, we see that predicted prices predominantly reflect variation in the average exporter-specific level of prices.

To illustrate the role of productivity thresholds in determining prices, I plot the threshold term in the price formula against income of the source country in the lower right hand graph. Two important points stand out here. First, variation in the threshold term is quite small overall and is thus unable to explain a large portion of the variation in import prices. Second, variation in the threshold term works in different directions in the two sectors. For Polymerization Products, the threshold term is negatively correlated with source country income and thus actually works in the wrong direction for understanding prices. This is because rich countries have low bilateral export thresholds relative to poor countries in this sector. Combined with the fact that the price schedule is upward sloping in this sector, lower thresholds for rich countries translate into lower prices as a result. Because the price schedule is positively sloped in most sectors, this pattern is quite common. However, as the bottom right panel for Men's Outerwear shows, there are cases in which the threshold component of prices contributes positively to explaining price differences between rich and poor countries. In this sector, the price schedule is downward sloping in productivity. Therefore, low productivity thresholds for wealthy countries generate higher prices. In both cases, however, the contribution of the threshold term of the price equation is quite small relative to the role of exporter-specific costs in understanding the pattern of US import prices.

In contrast to these results for prices, variation in bilateral productivity thresholds explains a substantial portion of variation in exports. To quantify the role of productivity thresholds, I decompose the variance of predicted trade in the model into components associated with bilateral thresholds and a composite of all other components. Of course, these two subcomponents are not independent.⁵⁰ I divide this covariance evenly between the two components in calculating their respective shares.⁵¹ Figure 11 contains the resulting share of the variation in predicted exports accounted for by variation in thresholds. On average, thresholds account for around half

⁵⁰The covariance of the two components is positive in 88 out of 141 sectors. It does not vary across sectors in a systematic manner.

⁵¹This shortcut has the consequence that the share of variance of predicted trade accounted for by the endogenous threshold is not bounded above by one. An alternative would be to attribute the entire covariance to the non-threshold term. The results of that calculation are similar, with slightly more than 50% of variation in predicted trade accounted for by threshold variation.

of the total variation in predicted trade. Given that the model accounts for around 80% of the total variance in trade, then thresholds account may account for as much as 40% of the total variation in exports. This suggests a very large role for endogenous non-tradability in explaining trade volumes.

To illustrate the good fit of the model along this dimension, I purge log exports of the estimated exporter and importer fixed effects and the direct effect of trade costs and plot the resulting residual exports against the expected value of the Probit index $\mathbf{E}[X_{ij}\hat{\theta}^*|\cdot, T_{ij} = 1]$ for two sectors (SITC categories 781 and 659). I then superimpose on this plot the predicted value of the threshold term in the export equation along with a composite of the threshold term and the selection term. As is evident in Figure 12, the data is tightly clustered and clearly positively related to $\mathbf{E}[X_{ij}\hat{\theta}^*|\cdot, T_{ij} = 1]$. To the extent that poor countries tend to have lower productivity thresholds on average, then this strong positive relationship would suggest that one reason they export lower volumes than rich countries is that a smaller fraction of firms in these countries export. Also, the values of trade predicted by the model match up quite closely with the data. Variation in the threshold term does most of the work in matching the overall pattern of the data. However, in the lower tail, the selection effect plays a larger role. The selection effect is actually negative in these two sectors, and is generally negative in most sectors. This selection effect plays only a small role in accounting for trade volumes overall.

4.3.3 Cross-Country Quality and Variety

One advantage to using price data in studying trade patterns is that it provides a means to identify separately the role of prices and latent quality and/or variety in generating observed export quantities. Following the procedure outlined in Section 3.5, I combine the estimated price of the most productive firm in each sector with the estimated exporter fixed effect in the trade equation to calculate a country-specific variety/quality index. In doing so, I take estimates of the elasticity of demand for U.S. SITC 3-Digit imports from Broda and Weinstein (2006). Further, I normalize the quality-variety composite of the United Kingdom to one in each sector and report measures of the country-specific index as proportional deviations from this numeraire country.⁵²

In line with intuition, the imputed quality-variety composite covaries strongly with exporter income per capita. For reference, Figure 13 plots the quality-variety composite versus exporter income for four sectors used in previous figures. In all four cases, we find a statistically significant positive relationship. This result holds more generally as well. Extending the calculation to all sectors, 69% of the 141 sectors have a statistically significant positive slope at the 10% level or

⁵²Because the U.S. exporter fixed effect is polluted by differences in units, I exclude the U.S. from these calculations.

higher. Only 4% of the sectors have a statistically significant negative slope.⁵³ Thus, combining price and export value information strongly suggests that rich countries produce higher quality goods and/or produce a larger variety of goods within sectors. Furthermore, the positive point estimates are distributed evenly across sectors, meaning that wealthier countries appear to enjoy superior quality/variety across the board in manufacturing. A main challenge for future work is to decompose this composite into quality and variety sub-components.

5 Concluding Comments

This paper establishes that ignoring product quality differences across firms produces counterfactual predictions for export prices. By contrast, a model in which high productivity firms choose to produce high quality goods and charge high unit prices is consistent with the most common pattern of export prices. As a side benefit, the estimates also shed light on the relationship between productivity, quality choices, and prices at the plant level.

These results have (at least) two implications for future research. First, one profitable avenue for future work consists of careful examination of firm level prices and exports in census-style data, especially where that data contains information on firm-level export behavior. Examination of price data in these sources could yield substantial new insights into industrial structure and trade participation decisions. Moreover, from a technical perspective, firm level data would permit the researcher to accommodate richer interaction between productivity heterogeneity, quality heterogeneity, and demand-side forces in determining prices and selection into exporting than I am able to allow for using aggregate data alone. Second, the results in this paper indicate that one should be cautious in using the benchmark model to study the behavior of prices and Balassa-Samuelson type real exchange rate effects. Replicating Balassa-Samuelson requires that the price of non-traded goods on average is higher than that of traded goods. The empirical results suggest that the opposite holds in many manufacturing sectors.

More generally, I find that productivity thresholds play a limited role in explaining cross-country variation in prices. Rather, nearly half of the total variation in prices is accounted for by country-specific factors common to all destination markets. This implies that research aimed identifying the sources of this vertical differentiation across countries could go a long way toward explaining the data. In contrast, productivity thresholds appear to play a large role in explaining exports. Future research into the sources of variation in export thresholds across destinations and across source countries, determinants of fixed export costs, could substantially improve our understanding of trade patterns.

⁵³Tabulating positive and negative slopes without regard to significance, 84% of the point estimates are positive.

Appendix A

This appendix sketches the general equilibrium solution to the endogenous quality model presented in Section 1. Most of the model has been described previously in the main text. The main component of the model yet to be specified is the procedure via which firms decide to enter and produce. Similar to Ghironi and Melitz (2005), I assume that firms are ex-ante identical and pay a fixed cost f_{Ei} units of labor for the right to draw idiosyncratic productivity z from a distribution $G(z)$. Because this cost is sunk, all firms produce post. To close the model, I will assume that trade is balanced in the aggregate for each country.

Much of the model solution, has been detailed in the main text, including the solution to the consumer's problem, the firm's optimal pricing and quality choice decision, and firm decisions about whether to export. I restate those results here in bullet point form.

- The consumer in country i allocates consumption across available varieties according to:

$$c_{ij}(z) = [\lambda_j(z)]^{\sigma-1} \left(\frac{\tau_{ji} p_j(z)}{P_i} \right)^{-\sigma} C_i, \quad (25)$$

where $c_{ij}(z)$ indicates consumption by a consumer in country i of a variety with idiosyncratic productivity z produced in country j and C_i is aggregate consumption as defined in the text. Further, I assume $\tau_{ii} = 1$. Exhaustion of the budget constraint for the consumer implies that $P_i C_i = w_i L_i$.

- The firm chooses prices and quality as described in the main text, leading to optimal prices and quality choices that are a function of the firm's idiosyncratic productivity:

$$p_i(z) = \left(\frac{\sigma}{\sigma-1} \right) \frac{w_i \lambda_i(z)^\beta}{Z_i z} \quad (26)$$

$$\lambda_i(z) = \lambda_i z^\alpha, \quad (27)$$

with λ_i defined as in the main text.

- The zero profit condition for the marginal exporting firm to each market pins down z_{xij} for $j \neq i$ as:

$$z_{xij} = \left[\frac{\sigma}{\sigma-1} \frac{w_i \lambda_i^{\beta-1}}{Z_i} \frac{P_j}{\tau_{ij}} \left(\frac{\sigma f_{xij}}{E_j} \right)^{1/(\sigma-1)} \right]^{1/(1-\alpha\beta+\alpha)}, \quad (28)$$

with $E_i = P_i C_i$. Combined with the fact that z has distribution $G(z)$ in each country, then these productivity thresholds pin down the number of firms exporting to each market as: $N_{xij} = N_i (1 - G(z_{xij}))$.

With these preliminaries, it remains to clearly define $\{P_i\}$ and solve for the collection of endogenous variables $\{w_i, N_i\}$ necessary to evaluate the expressions above. To do so, I follow Melitz (2003) and Ghironi and Melitz (2005) in defining convenient productivity aggregates that allow me to write the equilibrium conditions in terms of the behavior of representative domestic firms and representative exporters. Thus, I define the productivity of a representative firm located in country i producing for the home market as $\tilde{z}$ and a representative exporter from i to j as $\tilde{z}_{xij}$ where:

$$\begin{aligned}\tilde{z} &= \left[\int_{z_L}^{z_H} z^{(1-\alpha\beta+\alpha)(\sigma-1)} dG(z) \right]^{1/(1-\alpha\beta+\alpha)(\sigma-1)} \\ \tilde{z}_{xij} &= \left[\int_{z_{xij}}^{z_H} z^{(1-\alpha\beta+\alpha)(\sigma-1)} dG(z) \right]^{1/(1-\alpha\beta+\alpha)(\sigma-1)}.\end{aligned}$$

These expressions are similar to those in Ghironi and Melitz (2005). The only difference is the addition here of the term $(1 - \alpha\beta + \alpha)$ multiplying $(\sigma - 1)$. With these definitions in hand, it is straightforward to define the aggregate price level in each country in terms of the quality-adjusted price charged by the representative domestic firm and representative exporters from each destination that serves the domestic market:

$$P_i = \left[N_i \tilde{p}_i(\tilde{z})^{1-\sigma} + \sum_{j \neq i} N_{xji} [\tau_{ji} \tilde{p}_j(\tilde{z}_{xji})]^{1-\sigma} \right]^{1/(1-\sigma)}. \quad (29)$$

Ultimately, the aggregate price level is a function of $\{w_i, N_i\}$ just as all the other objects defined above. If there are I countries in total, then the combination of I free entry conditions and $(I - 1)$ balanced trade conditions define the number of firms in each country and relative wages across countries up to the definition of a numeraire (say $w_1 = 1$).

Free entry requires that the expected value of profits conditional on entry is equal to the fixed cost of entry. To write the free entry condition, I define the profits of the representative domestic firm and representative exporters for each destination market as:

$$\begin{aligned}\pi_i(\tilde{z}) &= \frac{1}{\sigma} \left(\frac{\tilde{p}_i(\tilde{z})}{P_i} \right)^{1-\sigma} (w_i L_i) - \frac{w_i \lambda_i(\tilde{z})^\phi}{Z_i} f \\ \pi_i(\tilde{z}_{xij}) &= \frac{1}{\sigma} \left(\frac{\tilde{p}_i(\tilde{z}_{xij}) \tau_{ij}}{P_j} \right)^{1-\sigma} (w_j L_j) - f_{xij},\end{aligned}$$

where I have used the fact that $E_i = w_i L_i$ and the profits of the representative home firm are expressed net of the cost of upgrading quality. Then, since there are ex-post N_i domestic firms

and N_{xij} exporters to each destination market, the free entry condition can be written as:

$$N_i \pi_i(\tilde{z}) + N_{xij} \pi_i(\tilde{z}_{xij}) = N_i (w_i f_{Ei}). \quad (30)$$

Finally, I write aggregate exports from country i to j using the definition of the representative exporter's productivity:

$$EX_{ij} = N_{xij} \left(\frac{\tilde{p}_i(\tilde{z}_{xij}) \tau_{ij}}{P_j} \right)^{1-\sigma} (w_j L_j),$$

where I again appeal to the fact that $E_i = w_i L_i$ to express exports explicitly in terms of wages. Then the balanced trade conditions take the form:

$$\sum_{j \neq i} EX_{ij} = \sum_{j \neq i} EX_{ji}. \quad (31)$$

Using the appropriate definitions, we can reduce the system down to the following collection of endogenous variables $\{c_{ij}(z), p_i(z), \lambda_i(z), z_{xij}, P_i, w_i, N_i\}$ for each country. Equations (25)-(29) for I countries plus (I-1) balanced trade conditions as in (31) then define a monopolistically competitive equilibrium for the world economy.

Appendix B

This appendix describes procedures I use for dealing with several problems that arise in working with the quantity data and provides details on the trade cost measures used in estimating the model. In unreported work, I have experimented with alternative procedures dealing with the problems in the quantity data and found the estimation results to be robust to the exact procedure used.

There are several complications that arise due to differences in the way quantity units are recorded across countries and sectors. Due to the manner in which the Feenstra-Lipsey data were assembled, units are not always homogeneous within sectors or for individual countries. When there are multiple units within a sector, I discard prices associated with the minority unit. In practice, this results in a small, quasi-random loss of data. In the vast majority of sectors, this results in a loss of somewhere between 1-5% of price observations. Some sectors lose no data, and the maximum loss is around 25% in the Feenstra-Lipsey data. In the US data, the problem is somewhat larger because the US simply has a larger number units categories. Usually the problem manifests itself as observing two different prices for exports to each destination in a sector. In this event, I drop the minority set of units. In addition, sometimes quantities and units are simply missing either for part or all of a country's trade with a specific partner. When

quantities are missing for a majority of trade for a given exporter to a specific destination, I treat that category as if I observe no quantity and hence no price. Whereas quantities/prices are available for nearly all US trade, quantity data is somewhat patchier in the Feenstra-Lipsey data. Missing data appear to be due principally to quasi-random reporting gaps and do not follow obvious systematic patterns. Nearly all countries in the sample have prices for upwards of 80-90% of the value of exports. A further complication arises because US-sourced trade data is reported in entirely different quantity units than the Feenstra-Lipsey data. This has two implications. First, the US fixed effect in the price equation picks up both variation in average prices in the US relative to the rest of the world as well as differences in units. As a result, all the analysis in the body of the paper that uses the estimated fixed effects omits the US. Second, I include a US importer fixed effect as well in the price regression to purge the effects of units differences from prices associated with exports to the US.

Finally, the price data contain a small but influential number of outlying prices. These appear to be due to measurement error in the data, and therefore I remove these observations. Specifically, I remove observations that differ from the median price in a sector by more than a factor of five. Purging observations that differ by more than a factor of ten yields similar results.

Turning to measurement of trade costs, I take most of these measures directly from Helpman, Melitz, and Rubinstein (2007). Marc Melitz graciously provided me with most of the data used in their paper. The only exceptions were categorical variables classifying islands and landlocked countries. I constructed these using the CIA World Fact Book. A few of the variable definitions deserve some extra comments. The common religion variable is a continuous variable equal to: $(\% \text{ Protestants in country } i \cdot \% \text{ Protestants in country } j + \% \text{ Catholics in country } i \cdot \% \text{ Catholics in country } j + \% \text{ Muslims in country } i \cdot \% \text{ Muslims in country } j)$. The common legal system variable takes on a value of one if the importing and exporting country share the same legal origin, and the colonial ties variable takes the value one if either country was once a colony of the other. In addition to these trade cost variables used in the main text, I have experimented with policy-type variables, including free trade areas, WTO membership, and currency unions and obtained roughly identical results to those reported.

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Table 1: Countries Included in Estimation Sample

AFGHANISTAN	GUATEMALA	PANAMA
ALBANIA	GUINEA	PAPUA NEW GUINEA
ALGERIA	GUINEA-BISSAU	PARAGUAY
ANGOLA	GUYANA	PERU
ARGENTINA	HAITI	PHILIPPINES
AUSTRALIA	HONDURAS	POLAND
AUSTRIA	HONG KONG	PORTUGAL
BANGLADESH	HUNGARY	ROMANIA
BELGIUM	ICELAND	RUSSIA
BELIZE	INDIA	SAUDI ARABIA
BENIN	INDONESIA	SENEGAL
BOLIVIA	IRAN	SEYCHELLES
BRAZIL	IRAQ	SIERRA LEONE
BULGARIA	IRELAND	SINGAPORE
BURKINA FASO	ISRAEL	SOUTH AFRICA
BURUNDI	ITALY	SOUTH KOREA
CAMBODIA	JAMAICA	SPAIN
CAMEROON	JAPAN	SRI LANKA
CANADA	JORDAN	ST KITTS NEVIS
CENTRAL AFR REP	KENYA	SUDAN
CHAD	KIRIBATI	SURINAM
CHILE	KUWAIT	SWEDEN
CHINA	LAOS	SWITZERLAND
COLOMBIA	LEBANON	SYRIA
COSTA RICA	MADAGASCAR	TAIWAN
COTE D'IVOIRE	MALAWI	THAILAND
DENMARK	MALAYSIA	TOGO
DJIBOUTI	MALI	TRINIDAD-TOBAGO
DOMINICAN REP	MAURITANIA	TUNISIA
ECUADOR	MAURITIUS	TURKEY
EGYPT	MEXICO	UGANDA
EL SALVADOR	MONGOLIA	UNITED KINGDOM
EQ GUINEA	MOROCCO	UNITED ARAB EM
ETHIOPIA	MOZAMBIQUE	TANZANIA
FIJI	NEPAL	URUGUAY
FINLAND	NETHERLANDS	USA
FRANCE	NEW ZEALAND	VENEZUELA
GABON	NICARAGUA	VIETNAM
GAMBIA	NIGERIA	YEMEN
GERMANY	NORWAY	ZAMBIA
GHANA	OMAN	ZIMBABWE
GREECE	PAKISTAN	

Table 2: Representative First Stage Probit Regression Results

	SITC 511	SITC 584	SITC 655	SITC 683	SITC 721	SITC 762	SITC 821	SITC 894
	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se	Coef./se
log distance	-.614*** (.057)	-.580*** (.070)	-.689*** (.053)	-.491*** (.075)	-.392*** (.057)	-.476*** (.068)	-.485*** (.050)	-.395*** (.049)
language	.202* (.112)	.213 (.144)	.363*** (.102)	-.026 (.169)	.398*** (.113)	.231 (.140)	.358*** (.090)	.390*** (.100)
legal system	.117 (.080)	.174* (.103)	.073 (.078)	.453*** (.120)	.033 (.089)	.418*** (.107)	.156** (.072)	.056 (.080)
religion	.133 (.169)	.027 (.229)	-.169 (.157)	-.518* (.305)	.220 (.187)	-.142 (.222)	.239* (.138)	.290* (.149)
colonial	-.295 (.205)	.361 (.252)	.003 (.190)	.376 (.292)	.178 (.189)	-.085 (.267)	.261 (.180)	.442** (.183)
common border	.288* (.174)	.642*** (.237)	.286* (.167)	.117 (.290)	.396** (.196)	.342 (.232)	.612*** (.166)	.065 (.182)
landlock	.558 (.559)	.744 (.652)	-.353 (.469)	-.280 (.616)	-.091 (.415)	-.733 (.466)	.879 (.669)	.727 (.676)
island	-.308 (.301)	-.250 (.314)	.194 (.240)	-.002 (.356)	.065 (.259)	-.456 (.342)	.145 (.214)	.152 (.218)
lagfrac	2.117*** (.140)	2.296*** (.175)	2.101*** (.138)	2.094*** (.196)	2.230*** (.148)	1.820*** (.177)	2.504*** (.141)	2.689*** (.142)
Pseudo R^2	.654	.650	.643	.618	.657	.641	.711	.699
Obs.	6772	3948	7884	2865	6893	4086	11712	9266

Notes: Exporter and Importer fixed effects included in all regressions. Standard Errors in Parentheses. * p<.10, ** p<.05, *** p<.01

Table 3: Ranking of US Export Destinations

1	MEXICO	42	JAMAICA	83	AUSTRALIA
2	UNITED KINGDOM	43	PARAGUAY	84	SURINAM
3	GERMANY	44	ALGERIA	85	MAURITIUS
4	FRANCE	45	CHINA	86	IRAQ
5	SPAIN	46	EL SALVADOR	87	SENEGAL
6	BRAZIL	47	KENYA	88	GUINEA
7	PHILIPPINES	48	ST KITTS NEVIS	89	MALAYSIA
8	ITALY	49	OMAN	90	CHILE
9	SOUTH KOREA	50	GHANA	91	SIERRA LEONE
10	IRELAND	51	RUSSIA	92	SINGAPORE
11	VENEZUELA	52	IRAN	93	UNITED ARAB EM
12	PERU	53	CANADA	94	PAPUA NEW GUINEA
13	SWEDEN	54	TRINIDAD-TOBAGO	95	TOGO
14	POLAND	55	ROMANIA	96	UGANDA
15	ARGENTINA	56	NEPAL	97	MAURITANIA
16	COLOMBIA	57	BOLIVIA	98	MALAWI
17	AUSTRIA	58	ANGOLA	99	HONG KONG
18	BELGIUM	59	SRI LANKA	100	EQ GUINEA
19	SOUTH AFRICA	60	JORDAN	101	CAMBODIA
20	DENMARK	61	BULGARIA	102	VIETNAM
21	TURKEY	62	PAKISTAN	103	MADAGASCAR
22	NORWAY	63	LEBANON	104	KIRIBATI
23	SWITZERLAND	64	BELIZE	105	FIJI
24	FINLAND	65	TAIWAN	106	BURKINA FASO
25	PORTUGAL	66	MOROCCO	107	MALI
26	HUNGARY	67	THAILAND	108	MONGOLIA
27	SAUDI ARABIA	68	NEW ZEALAND	109	MOZAMBIQUE
28	PANAMA	69	BANGLADESH	110	BENIN
29	GREECE	70	HAITI	111	KUWAIT
30	ECUADOR	71	GABON	112	ALBANIA
31	GUATEMALA	72	SYRIA	113	SUDAN
32	NIGERIA	73	GUYANA	114	GAMBIA
33	JAPAN	74	COTE D'IVOIRE	115	SEYCHELLES
34	DOMINICAN REP	75	TUNISIA	116	GUINEA-BISSAU
35	ICELAND	76	ZIMBABWE	117	AFGHANISTAN
36	COSTA RICA	77	ISRAEL	118	LAOS
37	URUGUAY	78	TANZANIA	119	INDIA
38	NETHERLANDS	79	ZAMBIA	120	CENTRAL AFR REP
39	EGYPT	80	NICARAGUA	121	YEMEN
40	HONDURAS	81	ETHIOPIA	122	CHAD
41	INDONESIA	82	CAMEROON	123	DJIBOUTI

Notes: Destinations are ranked by trade-weighted average Probit Index for all sectors. Low numbers indicate high probability of trade and low threshold productivity cutoff. See main text for details.

Table 4: Estimates and Standard Errors For $\bar{\delta}_1$ and $\bar{\delta}_2$

SITC 3-Digit	$\bar{\delta}_1$	SE($\bar{\delta}_1$)	$\bar{\delta}_2$	SE($\bar{\delta}_2$)	SITC 3-Digit	$\bar{\delta}_1$	SE($\bar{\delta}_1$)	$\bar{\delta}_2$	SE($\bar{\delta}_2$)	SITC 3-Digit	$\bar{\delta}_1$	SE($\bar{\delta}_1$)	$\bar{\delta}_2$	SE($\bar{\delta}_2$)	SITC 3-Digit	$\bar{\delta}_1$	SE($\bar{\delta}_1$)	$\bar{\delta}_2$	SE($\bar{\delta}_2$)
511	1.30	0.28	1.54	0.27	652	1.70	0.26	1.76	0.26	697	1.12	0.25	1.10	0.25	775	1.02	0.26	1.04	0.26
512	0.64	0.42	0.77	0.41	653	1.50	0.22	1.53	0.22	699	0.92	0.21	0.90	0.21	776	1.35	0.36	1.10	0.38
513	0.73	0.40	0.84	0.39	654	1.47	0.36	1.55	0.35	711	0.32	0.96	0.32	0.97	778	0.74	0.38	0.68	0.39
514	0.86	0.24	0.86	0.25	655	1.57	0.26	1.57	0.26	712	0.90	0.67	1.10	0.65	781	1.54	0.26	1.52	0.27
515	1.54	0.35	1.66	0.34	656	1.00	0.36	1.04	0.36	713	1.41	0.22	1.61	0.22	782	1.56	0.30	1.59	0.30
516	0.69	0.39	0.87	0.37	657	1.00	0.28	1.06	0.28	714	1.17	0.42	1.15	0.43	783	1.48	0.44	1.58	0.44
522	1.01	0.30	1.14	0.29	658	1.36	0.26	1.33	0.26	716	1.23	0.33	1.28	0.33	784	0.99	0.27	1.06	0.26
523	1.03	0.25	1.16	0.25	659	1.73	0.36	1.72	0.36	718	0.73	0.40	0.83	0.39	785	1.12	0.32	1.03	0.33
531	1.05	0.31	1.19	0.30	661	1.14	0.28	1.27	0.28	721	1.01	0.37	1.17	0.35	786	1.05	0.37	0.98	0.38
533	0.92	0.20	0.95	0.19	662	1.28	0.21	1.34	0.21	722	1.90	0.40	1.83	0.41	791	1.32	0.49	1.44	0.48
541	0.84	0.20	0.81	0.21	663	0.76	0.29	0.89	0.28	723	1.65	0.32	1.72	0.32	792	1.36	0.39	1.30	0.39
551	0.96	0.22	1.00	0.22	664	1.20	0.28	1.27	0.28	724	0.84	0.41	0.89	0.41	793	0.84	0.55	0.83	0.56
553	1.19	0.23	1.24	0.23	665	1.27	0.25	1.27	0.26	725	0.63	0.38	0.79	0.35	812	0.72	0.24	0.74	0.24
554	0.93	0.22	1.02	0.21	666	0.63	0.34	0.68	0.34	726	0.86	0.31	0.91	0.31	821	0.88	0.24	0.90	0.24
562	1.13	0.28	1.22	0.28	671	1.29	0.36	1.31	0.37	727	0.47	0.33	0.48	0.33	831	0.90	0.44	0.81	0.46
572	1.15	0.40	1.29	0.41	672	1.90	0.38	2.01	0.38	728	0.37	0.33	0.39	0.33	842	2.02	0.37	1.95	0.38
582	1.03	0.24	1.02	0.25	673	1.18	0.26	1.24	0.25	736	0.93	0.40	0.98	0.40	843	1.59	0.26	1.53	0.26
583	1.02	0.24	1.05	0.24	674	1.42	0.24	1.49	0.24	737	0.69	0.48	0.78	0.47	844	1.34	0.31	1.24	0.32
584	1.00	0.35	1.04	0.35	676	0.90	0.56	1.02	0.56	741	1.29	0.31	1.35	0.31	845	1.39	0.26	1.27	0.27
585	0.37	0.59	0.31	0.62	677	0.70	0.30	0.76	0.29	742	1.12	0.32	1.20	0.32	846	1.57	0.37	1.49	0.38
591	0.91	0.27	0.95	0.27	678	1.17	0.21	1.23	0.21	743	1.11	0.34	1.14	0.34	847	0.99	0.33	0.91	0.34
592	1.02	0.25	1.18	0.24	679	1.06	0.31	1.12	0.31	744	1.07	0.35	1.23	0.34	848	1.06	0.32	0.87	0.34
598	0.79	0.28	0.91	0.27	682	1.19	0.30	1.29	0.30	745	0.75	0.29	0.80	0.28	851	1.12	0.37	1.01	0.39
611	1.37	0.28	1.51	0.28	683	1.27	0.45	1.32	0.45	749	0.88	0.28	0.98	0.28	871	0.63	0.48	0.50	0.52
612	1.06	0.28	0.89	0.30	684	1.29	0.20	1.41	0.20	751	0.81	0.43	0.78	0.44	872	0.77	0.28	0.67	0.30
613	1.43	0.47	1.17	0.51	685	0.59	0.85	0.79	0.79	752	1.09	0.27	1.02	0.28	873	1.34	0.41	1.22	0.43
621	0.72	0.27	0.77	0.27	686	1.27	0.38	1.33	0.38	759	0.58	0.23	0.32	0.27	874	0.80	0.38	0.75	0.38
625	1.64	0.25	1.64	0.26	687	1.24	0.46	1.33	0.46	761	2.01	0.35	1.98	0.35	881	0.83	0.56	0.64	0.61
628	0.63	0.39	0.69	0.38	689	1.14	0.54	1.02	0.56	762	1.81	0.48	1.62	0.50	882	1.21	0.36	1.27	0.36
633	0.70	0.64	0.66	0.65	691	1.17	0.30	1.29	0.29	763	0.94	0.35	0.89	0.36	884	0.39	1.03	0.09	1.26
634	1.26	0.25	1.34	0.25	692	0.87	0.31	0.94	0.30	764	1.09	0.29	1.05	0.29	892	0.75	0.22	0.89	0.21
635	1.15	0.26	1.28	0.26	693	0.96	0.28	1.05	0.27	771	1.21	0.28	1.06	0.30	893	0.86	0.28	0.86	0.28
641	1.22	0.21	1.30	0.21	694	0.67	0.21	0.72	0.20	772	0.83	0.23	0.74	0.24	894	0.68	0.32	0.63	0.33
642	1.08	0.23	1.12	0.23	695	0.56	0.37	0.47	0.39	773	0.97	0.25	0.89	0.25	895	0.55	0.38	0.53	0.38
651	1.23	0.22	1.30	0.22	696	0.72	0.40	0.68	0.41	774	0.92	0.37	0.76	0.39	898	0.56	0.36	0.58	0.36

Notes: See main text for details.

Table 5: Estimates and Standard Errors of Price Equation Slope

SITC 3-Digit	$\bar{\delta}_2 - \bar{\delta}_1$	SE($\bar{\delta}_2 - \bar{\delta}_1$)	SITC 3-Digit	$\bar{\delta}_2 - \bar{\delta}_1$	SE($\bar{\delta}_2 - \bar{\delta}_1$)	SITC 3-Digit	$\bar{\delta}_2 - \bar{\delta}_1$	SE($\bar{\delta}_2 - \bar{\delta}_1$)	SITC 3-Digit	$\bar{\delta}_2 - \bar{\delta}_1$	SE($\bar{\delta}_2 - \bar{\delta}_1$)
511	0.24	0.04	652	0.06	0.03	697	-0.01	0.03	775	0.02	0.03
512	0.13	0.05	653	0.03	0.03	699	-0.03	0.02	776	-0.26	0.08
513	0.11	0.04	654	0.08	0.04	711	0.00	0.11	778	-0.06	0.05
514	-0.01	0.04	655	-0.01	0.03	712	0.20	0.12	781	-0.02	0.02
515	0.11	0.06	656	0.05	0.04	713	0.20	0.03	782	0.03	0.04
516	0.19	0.05	657	0.06	0.03	714	-0.02	0.06	783	0.10	0.06
522	0.13	0.05	658	-0.04	0.03	716	0.04	0.03	784	0.08	0.02
523	0.13	0.04	659	-0.01	0.05	718	0.10	0.05	785	-0.09	0.04
531	0.13	0.03	661	0.12	0.05	721	0.16	0.04	786	-0.07	0.04
533	0.03	0.02	662	0.06	0.04	722	-0.07	0.06	791	0.13	0.06
541	-0.03	0.05	663	0.13	0.05	723	0.07	0.04	792	-0.06	0.06
551	0.05	0.03	664	0.07	0.04	724	0.05	0.06	793	-0.01	0.10
553	0.05	0.03	665	0.00	0.04	725	0.16	0.05	812	0.02	0.03
554	0.08	0.02	666	0.04	0.04	726	0.05	0.04	821	0.02	0.02
562	0.09	0.04	671	0.02	0.05	727	0.00	0.04	831	-0.09	0.04
572	0.14	0.10	672	0.11	0.04	728	0.02	0.04	842	-0.07	0.02
582	-0.01	0.02	673	0.07	0.03	736	0.05	0.04	843	-0.06	0.03
583	0.03	0.02	674	0.07	0.02	737	0.09	0.05	844	-0.10	0.04
584	0.05	0.04	676	0.12	0.09	741	0.06	0.02	845	-0.12	0.03
585	-0.06	0.10	677	0.07	0.03	742	0.08	0.03	846	-0.07	0.03
591	0.05	0.04	678	0.06	0.03	743	0.03	0.03	847	-0.08	0.04
592	0.16	0.03	679	0.06	0.04	744	0.16	0.03	848	-0.19	0.06
598	0.13	0.03	682	0.10	0.02	745	0.05	0.03	851	-0.10	0.04
611	0.14	0.03	683	0.05	0.03	749	0.10	0.03	871	-0.13	0.09
612	-0.18	0.05	684	0.12	0.02	751	-0.03	0.05	872	-0.10	0.05
613	-0.26	0.11	685	0.20	0.09	752	-0.06	0.03	873	-0.12	0.08
621	0.05	0.03	686	0.06	0.03	759	-0.26	0.07	874	-0.05	0.03
625	0.00	0.02	687	0.09	0.05	761	-0.02	0.04	881	-0.19	0.08
628	0.06	0.04	689	-0.12	0.10	762	-0.19	0.07	882	0.06	0.05
633	-0.04	0.08	691	0.12	0.03	763	-0.05	0.05	884	-0.30	0.27
634	0.08	0.03	692	0.06	0.03	764	-0.05	0.03	892	0.14	0.03
635	0.13	0.03	693	0.09	0.03	771	-0.15	0.05	893	0.00	0.02
641	0.09	0.02	694	0.06	0.03	772	-0.08	0.03	894	-0.05	0.04
642	0.03	0.02	695	-0.09	0.05	773	-0.08	0.03	895	-0.02	0.05
651	0.06	0.02	696	-0.04	0.05	774	-0.16	0.06	898	0.02	0.04
									899	0.07	0.05

Notes: Bold indicates that estimated price equation slope is significantly positive or negative in one-sided test at 10% level or higher. See main text for details.

Table 6: Tabulation of Price Equation Slopes

	$\bar{\delta}_2 - \bar{\delta}_1$	Linear Reg.	Linear Reg., US Only
positive	61%	64%	74%
positive & significant	48%	49%	22%
negative	39%	36%	26%
negative & significant	21%	23%	2%
Total sectors:	141	141	118

Notes: Column 1 reports tabulation for full non-linear estimation. Columns 2 and 3 report tabulation for linear regressions in full data and US export prices alone. “Significant” indicates that estimated slope is significantly positive or negative in one-sided test at 10% level or higher. See main text for details.

Figure 1: Trade Weighted Average of Predicted Probit Index by Importing Country vs. Real GDP of the Importer

Figure 2: Trade Weighted Average of Predicted Probit Index by Exporting Country vs. Real GDP Per Capita of the Exporter

Figure 3: Estimated Slope of the Prices Schedule ($\bar{\delta}_2 - \bar{\delta}_1$), by SITC 3-Digit Sector

Figure 4: Log Export Price for United Kingdom vs. Ranking of Destination Market by Productivity Threshold

Figure 5: Fraction of Total Variance in Log Prices Explained by Model, by SITC 3-Digit Sector

Figure 6: Fraction of Total Variance in Log Exports Explained by Model, by SITC 3-Digit Sector

Figure 7: Coefficients from Within-Sector Regressions of Actual and Predicted U.S. Import Prices on Exporter GDP Per Capita

Figure 8: Decomposition of Predicted Prices into Variances and Covariance of Exporter Fixed Effect and Threshold Term

Figure 9: Log Prices, Predicted Prices, and Estimated Components of Prices for U.S. Imports of Polyethylene vs. Log GDP Per Capita of Exporter

Figure 10: Log Prices, Predicted Prices, and Estimated Components of Prices for U.S. Imports of Men's Coats vs. Log GDP Per Capita of Exporter

Figure 11: Share of Variance in Predicted Trade Attributed to Productivity Thresholds

Figure 12: Log Exports Purged of Fixed Effects and Trade Costs with Predicted Threshold and Selection Terms

Figure 13: Estimated Index of Quality and Variety vs. Exporter Real GDP Per Capita