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Abstract: In this paper, we start with quantifying the worldwide tariff pass-through, i.e., the impact of tariff reductions on trade prices. We find that a 1% reduction of tariffs decreases trade prices by 0.1%, i.e., a negative tariff pass-through (Lerner paradox). To uncover the mechanism underlying this result, we decompose trade prices into product quality and quality-adjusted trade prices. As a result, we found that a 1% reduction of tariff rates decreases product quality by 1.2% and increases quality-adjusted trade prices by 1.1% (Metzler paradox). We construct a theoretical model that demonstrates the mechanism behind these empirical results. We suggest that both a firm-delocation mechanism under variable markups and a quality-sorting mechanism are the driving forces behind these empirical findings. Lastly, by employing this theoretical model, we also examine the welfare effect of tariff changes.

Keywords: Tariff pass-through; Import prices; Quality
JEL classification: F15, F53

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Lerner Meets Metzler:

Tariff Pass-through of Worldwide Trade

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Abstract: In this paper, we start with quantifying the worldwide tariff pass-through, i.e., the impact of tariff reductions on trade prices. We find that a 1% reduction of tariffs decreases trade prices by 0.1%, i.e., a negative tariff pass-through (Lerner paradox). To uncover the mechanism underlying this result, we decompose trade prices into product quality and quality-adjusted trade prices. As a result, we found that a 1% reduction of tariff rates decreases product quality by 1.2% and increases quality-adjusted trade prices by 1.1% (Metzler paradox). We construct a theoretical model that demonstrates the mechanism behind these empirical results. We suggest that both a firm-delocation mechanism under variable markups and a quality-sorting mechanism are the driving forces behind these empirical findings. Lastly, by employing this theoretical model, we also examine the welfare effect of tariff changes.

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1. Introduction

The impact of a tariff reduction or elimination on trade prices, a so-called "tariff pass-through," has long been studied in the international economics literature. Tariff pass-through is vital in considerations of whether and to what extent trade liberalization benefits households (Han et al., 2016) and whether it is a pro-poor policy in liberalizing countries (Marchand, 2012). Empirical findings on tariff pass-through are also important when we consider what kind of international trade rules should be set up. Bagwell and Staiger (1999)

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have theoretically shown that tariff reforms under a particular form of reciprocity rule improve all countries' welfare. However, depending on the magnitude and direction of the pass-through, this result of Bagwell and Staiger (1999) could be overturned (Bagwell and Staiger, 2016).[1] Understanding tariff pass-through is thus an essential issue for evaluating the effects of trade liberalization.

There are various possible degrees and directions of tariff pass-through. For instance, suppose that a country reduces its import tariff on a particular product. If foreign firms' export prices of that product remain unchanged, this tariff reduction is perfectly passed through to the consumer price, and consumers in that country fully capture the rents from this trade liberalization.[2] On the other hand, if the foreign firms raise their export prices in response to the tariff reduction, part of the rents goes to these firms, and the importing country's terms of trade deteriorate. Furthermore, if the increases in export prices are large enough, trade liberalization may even raise the consumer price in the importing country. Such an unusual consequence is known as a "Metzler paradox" (Metzler, 1949). Conversely, the possibility exists that a tariff reduction *decreases* export prices and consumers would gain more than the extent of tariff reduction, thereby improving the importing country's terms of trade. This case is referred to as a "Lerner paradox" (Lerner, 1936).

Existing empirical studies have quantified the tariff pass-through for particular countries, particular products such as textiles and apparel, and particular tariff preference schemes, such as Generalized System of Preferences (GSP). An early empirical work on the issue is that of Feenstra (1989), who investigated the tariff pass-through in the US imports from Japan using product-level import data. By employing firm-level export data, Ludema and Yu (2016) and Görg et al. (2017) investigated the tariff pass-through when exporting from the US and Hungary, respectively. Several studies have examined the effects of tariff reduction through preferential/regional trade agreements (RTAs) (Cadot et al., 2005; Olarreaga and Ozden, 2005; Ozden and Sharma, 2006; Cirera, 2014). These studies have found an incomplete tariff pass-through, i.e., only part of tariff reductions is passed onto trade prices. Among others, the firm-level study by Ludema and Yu (2016) showed that the Metzler paradox is possible because a tariff reduction may increase consumer prices in some cases.[3]

In this paper, we start with quantifying and investigating the worldwide tariff pass-through. Surprisingly, estimates of the tariff pass-through on worldwide trade are not available in the literature. One critical reason for unavailability of such estimates is that a ready-made database on worldwide tariffs had not been available until recently. Such a

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[1] Raimondos and Woodland (2018) proposed an alternative rule of reciprocity in tariff reforms that improves welfare without any assumptions regarding the price effects of tariff changes.

[2] In this paper, we do not differentiate among export prices, import prices, and trade prices, but use those three prices interchangeably. All these terms mean tariff-exclusive prices in this paper. Tariff-inclusive prices are called "consumer prices" in this paper.

[3] They called the case "quasi-Metzler paradox" because quality changes are reflected in their price changes.

database is now provided by the World Integrated Trade Solution (WITS). The database includes information on various kinds of tariff schemes, such as most favored nation (MFN), RTAs, or the GSP in almost all countries worldwide. Combining such tariff information with data on unit trade prices drawn from UN Comtrade, we estimate the global average of tariff pass-through. Our dataset includes bilateral trade between 70 importers and 172 exporters during 1992–2014, at the harmonized system (HS) six-digit level. Surprisingly, we found a robust result that the tariff reduction *decreases* trade prices, i.e., negative tariff pass-through. Specifically, it shows that a 1% reduction of (one plus) tariffs decreases trade prices by 0.1%.

To elucidate the mechanism underlying our result of this negative tariff pass-through, we decompose trade prices into product quality and quality-adjusted trade prices by employing the method proposed by Khandelwal et al. (2013). As a result, we found that a 1% reduction of (one-plus) tariff rates decreases product quality by 1.2% and increases quality-adjusted trade prices by 1.1%. As found above, for gross trade prices, the net effect is a 0.1% fall. The positive relationship between tariffs and quality is a key factor behind the negative pass-through. Namely, because the effect on product quality is absolutely larger than that on quality-adjusted prices, the net effect on gross trade prices becomes negative. In other words, we found a Lerner paradox for gross prices. This result is in sharp contrast with that of Ludema and Yu (2016), who theoretically and empirically found that a Metzler paradox is possible in that trade liberalization can increase consumer prices by enhancing quality upgrading of exported products. Furthermore, our results suggest that a 1% tariff reduction increases quality-adjusted trade prices by more than 1%, which implies that trade liberalization increases quality-adjusted consumer prices (i.e., Metzler paradox). In other words, Lerner meets Metzler in the sense that we observe a Metzler paradox for the quality-adjusted price and a Lerner paradox for the gross price at the same time.

Several theoretical studies might be useful to understand these empirical results. Some papers have clarified that unilateral trade liberalization may result in a Metzler paradox (Venables, 1987; Bagwell and Staiger, 2012; Bagwell and Lee, 2015).[4] Among them, Bagwell and Lee (2015) extended the heterogeneous-firm trade model of Melitz and Ottaviano (2008) and showed that a lower import tariff causes a firm-delocation effect, which reduces the competitiveness of the domestic market and raises the product-average consumer price.[5] Some papers have considered changes in product quality within the same framework (Antoniades, 2015: Ludema and Yu, 2016) and demonstrated that quality changes might lead to a Metzler paradox for gross prices at the firm level. Because we use product-level data on worldwide trade, our estimate is the product-average tariff pass-through, rather than the firm-specific tariff pass-through. Indeed, none of these papers can explain the presences of a Lerner paradox for average gross prices.

[4] Ishikawa and Mukunoki (2008) showed that a simultaneous reduction of tariffs with other importing countries may generate a Metzler paradox.

[5] Demidova (2017) showed that a Metzler paradox of Bagwell and Lee (2015) no longer holds if a homogenous good sector under perfect competition is removed from the model.

To formalize these empirical findings, we provide a model that incorporates both the firm-delocation mechanism of Melitz and Ottaviano (2008) and the quality-sorting mechanism of Baldwin and Harrigan (2011) or Johnson (2012). Baldwin and Harrigan (2011) and Johnson (2012) incorporated product quality into Melitz (2003) and provided a quality-sorting mechanism that explained a positive correlation between gross *average* export prices and bilateral trade barriers such as distance. Although these papers did not explicitly investigate the price effects of tariffs, their results indicate that quality sorting is a key mechanism behind existence of a Lerner paradox. These papers, however, did not explain the presence of a Metzler paradox for quality-adjusted prices. By formulating a quality-sorting mechanism in a Melitz-Ottaviano type model of firm-delocation, however, our model is able to provide the concurrence of a Lerner paradox for gross average prices and a Metzler paradox for quality-adjusted average prices, which is consistent with the empirical findings on worldwide trade. Namely, although a lower tariff decreases the average consumer price of imported products, it comes with even lower quality of these products and thereby increases quality-adjusted consumer prices.

Employing this theoretical model, which is able to explain our empirical results, allows us to also examine the welfare effect of these price changes. Seemingly, unilateral trade liberalization benefits consumers in the liberalizing country because it reduces consumer prices to a greater extent than the reductions in tariffs. However, this is not necessarily the case in our model, where unilateral trade liberalization leads to a substantial decline in the average quality of imported products but an increase in the quality-adjusted consumer price. Furthermore, unilateral trade liberalization decreases the number of product varieties available for consumers. Because of these effects, it can be concluded that unilateral trade liberalization worsens consumers' welfare in the liberalizing country. To guarantee consumer benefits from trade liberalization, additional policy instruments should accompany unilateral trade liberalization. For example, a competition policy that reduces the fixed cost of entry and enhances the domestic entry is one such possible instrument for the purpose.

In addition to the above literature on tariff pass-through, our study is related to at least two more bodies of literature. First, some studies have examined the effects of tariffs on firm performance rather than on export product prices. For example, Bustos (2011) explored the effect on firm innovation and found the statistically significant positive effects. Second, although the above literature has investigated the effects of tariffs in export destination countries, Bas and Strauss-Kahn (2015) and Fan et al. (2015) studied the impacts of "input tariffs" in export-origin countries. "Input tariff" refers to tariffs on products and intermediate goods used for production of a given export product. Those studies empirically found that a reduction of input tariffs enables firms to import higher-quality inputs and raises the quality of export products. The effects of input tariffs on firm performance indicators such as productivity were also examined in Amiti and Konings (2007).

The rest of this paper is organized as follows. The next section presents the global average of tariff pass-through. We also examine how a tariff change affects trade prices through changing product quality and quality-adjusted prices. In Section 3, we theoretically investigate the relationship of tariffs with gross prices, product quality, and quality-adjusted prices. Section 4 concludes.

2. Global Average of Tariff Pass-through

This section presents the global average of tariff pass-through. Specifically, after presenting results on the effect of tariffs on gross trade prices, we decompose their effects on quality-adjusted prices and quality.

2.1. Effects on Gross Prices

We begin with analyses of gross prices. As mentioned in the introductory section, we employ data from UN Comtrade for trade data and WITS for tariff data. Gross trade prices are computed by dividing trade values by trade quantities in terms of kilograms. We use trade data reported by importers. Our tariff variable is defined at a country pair-product-year level. Namely, we take into account the existence of preferential tariff rates such as RTA tariff rates and tariff rates for GSP. When multiple tariff schemes are available, we assume that exporters always use the scheme with lowest tariff rate. In both trade and tariff data, we consistently use the six-digit code from the 1992 HS version. Therefore, tariff rates defined at a tariff-line level are aggregated at the six-digit level by a simple average. As a result, our dataset is very comprehensive and includes 70 importers, 172 exporters, and 23 years (i.e., 1992–2014).[6]

With this dataset, we estimate the following simple equation:

$$\ln p_{hijt} = \beta \ln\left(1 + Tariff_{hijt}\right) + \mathbf{u} + \epsilon_{hijt},$$

where p_{hijt} represents before-tariff (tariff exclusive) trade price from country i to country j in product h at year t. As mentioned above, a product is defined at the HS six-digit level in our analysis. $Tariff_{hijt}$ is the aforementioned tariff rates of country i for product h imported from country j at year t. For example, when tariff rates are 10%, it takes a value of 0.10. Its coefficient β indicates the degree of tariff pass-through. Specifically, it shows how many percentages the trade prices change when (one-plus) tariff rates rise by 1%. $\mathbf{u}$ is various sets of fixed effects, which are explained later. ϵ_{hijt} is the disturbance term. We estimate this equation by ordinary least squares (OLS) method.[7]

[6] These countries are listed in Appendix A.

[7] One issue with this estimation may be the sample selection. Namely, given that we can observe the data on trade prices only when the concerned products are traded, our estimates may suffer from sample selection biases. The use of Heckman two-step estimation technique is one possible way to address this issue. However, our dataset is huge, including approximately 60 million observations. The estimation of non-linear models including the Heckman model with a larger number of dummy variables for such a

Our first specification for estimation includes exporter-importer-product and exporter-importer-year fixed effects. The former controls for various time-invariant factors such as geography, cultural factors, or demand elasticity. Time-variant country-pair specific factors are controlled for by the latter, including the existence of trade preferences (e.g., RTA) or exchange rates. The estimation result is shown in column (I) in Table 1. The coefficient for tariffs is estimated to be significantly positive, indicating a slight decrease in trade prices due to tariff reductions. Specifically, it shows that a 1% reduction of (one plus) tariffs decreases trade prices by 0.04%, i.e., consumer prices decrease by more than the extent of tariff reduction.

=== Table 1 ===

We further introduce fixed effects. In column (II), we add exporter-product-year fixed effects. This type of fixed effects will control for production condition in export countries, particularly wages. The coefficient for tariffs is again significant, but here, it is negative; this indicates that a tariff reduction raises trade prices. In column (III), we introduce importer-product-year fixed effects, which control completely for product-level demand size of importers. Furthermore, this type of fixed effects absorbs any variation in MFN rates among importers (although our sample importers include non-WTO member countries). Thus, in this specification, the variation in tariffs comes completely from preferential tariff rates. The coefficient for tariffs is again estimated to be positive.

To check the robustness of this positive coefficient, we estimate two other models.[8] In both models, we use the same set of fixed effects as those in column (III) in Table 1. First, based on the conservative classification of Rauch (1999), we estimate for differentiated products and non-differentiated products separately. The coefficients are significantly positive in both types of products although the absolute magnitude is slightly larger in the case of non-differentiated products. Second, we examine lagged effects of tariffs by introducing either or both one-year, three-year, and five-year lagged tariff variables in addition to the concurrent tariff variable. Although the significance of coefficients differs by specifications, the sign with statistical significance is always positive.

2.2. Effects on Quality-adjusted Trade Prices and Quality

In this subsection, to obtain clues on the mechanism underlying the positive effects of tariffs on gross trade prices, we decompose gross trade prices into the quality component and all other components. To this end, we employ the method proposed by Khandelwal et al. (2013). Specifically, we first estimate the following (demand) equation by the OLS:

$$\ln Q_{hijt} + \sigma_{hj} \ln\Big(\big(1 + Tariff_{hijt}\big) \times p_{hijt}\Big) = \mathrm{u}_h + \mathrm{u}_{jt} + \epsilon_{hijt},$$

number of observations is beyond the capacity of our computers. The basic statistics are reported in Table B1 in Appendix B.

[8] The result are given in Appendix B.

where $\ln Q_{hijt}$ is a log of trade quantity in terms of kilograms, σ_{hj} is demand elasticity of product h of importer j,[9] and u_h and u_{jt} are product and importer-year fixed effects, respectively. We introduce tariff rates on the left-hand side of the equation to approximate consumer prices. We estimate this equation by sections of HS tariff classifications. Then, we recover product quality z by computing

$$\ln \hat{z}_{hijt} = \hat{\epsilon}_{hijt} / \left(\sigma_{hj} - 1\right)$$

The log of quality-adjusted trade prices (*QaPrice*) is obtained as

$$\ln p_{hijt} - \ln \hat{z}_{hijt}.$$

Table 2 reports the estimates for similar specifications as in Table 1, here for quality-adjusted prices and quality separately.[10] In all specifications, the coefficients for tariffs are significantly negative for quality-adjusted prices and significantly positive for quality. For example, column (III) shows that a 1% reduction of (one-plus) tariff rates decreases product quality by 1.2% and increases quality-adjusted trade prices by 1.1%. Naturally, the sum of the coefficients for quality-adjusted prices and quality is equal to the coefficient found in Table 1. In particular, when the absolute magnitude is larger in the quality equation than in the quality-adjusted trade prices equation, as in columns (I) and (III), the coefficient in gross trade prices becomes positive.

=== Table 2 ===

We also estimate similar models as in the previous subsection for quality-adjusted trade prices and quality separately.[11] When estimating the model separately for trade in differentiated and non-differentiated products, we again obtain the negatively significant coefficient for quality-adjusted prices and the positively significant coefficient for quality. In addition, for both quality-adjusted trade prices and quality, the absolute magnitude is larger for differentiated products than non-differentiated products. When we introduce lagged tariff variables, we obtain similar results for the concurrent tariffs as found earlier for both quality-adjusted trade prices and quality equations. However, almost all lagged variables have the opposite sign to that found for the concurrent tariff variable. Nevertheless, the sum of the coefficients for one- and more-year lagged variables is much smaller than the coefficient for the concurrent tariff variable in terms of an absolute value. Therefore, the total effect is still negative for quality-adjusted trade prices and positive for quality.

In sum, we have shown that a tariff reduction in the destination country (1) *decreases*

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[9] Data on elasticities at country-HS three-digit level were obtained from Broda et al. (2017).

[10] There might be two empirical issues with our estimation. First, the demand function used in estimating the quality is based on the constant elasticity of substitution (CES) utility function. Nevertheless, the tariff pass-through rate is not necessarily perfect because we consider its *average* rate. The entry and exit of heterogenous firms in the export market, i.e., extensive margin, may change the average rate of tariff pass-through. Second, because the dependent variable in the demand function includes tariff rates, regressing quality (and quality-adjusted trade prices) on tariff rates yields an endogeneity concern. Furthermore, it is difficult to address this type of endogeneity bias. However, we consider that more serious biases in quality (and quality-adjusted trade prices) result from not taking into account the difference in tariff rates across countries, products, and years when estimating the demand equation.

[11] These results are available in Appendix B.

gross trade prices (negative tariff pass-through); (2) *decreases* the quality of exported products, and (3) increases quality-adjusted trade prices. The first result implies the presence of a Lerner paradox for gross trade prices. Furthermore, given our observation that the degree of increases in quality-adjusted trade prices is greater than the degree of tariff reduction, a tariff reduction also increases tariff-inclusive quality-adjusted prices. This implies the presence of a Metzler paradox for quality-adjusted trade prices. These results are different from those of Ludema and Yu (2016), who investigated how changes in foreign tariffs affect U.S. export prices at the firm level and found that a Metzler paradox is possible for the (quality-unadjusted) gross trade prices.

3. Theoretical Analysis

In this section, we build a model to explain our empirical results. The model incorporates a heterogeneous-quality model of Baldwin and Harrigan (2011) and Johnson (2012) into the heterogeneous-firm model of Melitz and Ottaviano (2008). In Melitz and Ottaviano (2008)'s model, firms' markups are variable, and trade liberalization affects the degree of market competition. Specifically, we consider a situation where firms with different productivity supply products with different quality.

3.1. Basic Setup

Our model contains two countries indexed by $j \in \{A, B\}$, and consumers in these countries have the same preference. There are (exogenously given) M product categories and one numéraire good in the economy, and producers supply varieties of products in each product category h. The representative consumer's utility function in country j is quasi-linear and given by

$$U^j = y^j + \sum_{h=1}^{M}\left[\alpha\int_{i\in\Omega} x_{hi}^j di - \frac{1}{2}\gamma\int_{i\in\Omega}\left(x_{hi}^j\right)^2 di - \frac{\eta}{2}\left(\int_{i\in\Omega} x_{hi}^j di\right)^2\right], \tag{1}$$

where y^j is the individual's consumption of the numéraire good, x_{hi}^j is the individual consumption of each variety $i \in \Omega$ of the product category h. This variety of consumption is measured in units of utility and defined as $x_{hi}^j = z_{hi}q_{hi}^j$, where z_{hi} is the quality of variety i and q_{hi}^j is the physical units of variety i. Note that the quality of each variety is common across markets. The parameter $\eta\ (> 0)$ captures the degree of substitutability among the varieties in the industry. As η becomes lower, products become more differentiated. Other parameters satisfy $\alpha > 0$ and $\gamma \geq 0$. The budget constraint of the representative consumer in country j is $y^j + \sum_{h=1}^{M}[\int_{i\in\Omega} p_{hi}^j q_{hi}^j di] \leq I^j$, where p_{hi}^j is the price of variety i and I^j is the consumer's income.

By maximizing Equation (1) with respect to q_{hi}^j, subject to the budget constraint, the inverse demand function for each variety is given by

$$p_{hi}^{j} = z_{hi}^{j}\left(\alpha - \gamma z_{hi} q_{hi}^{j} - \eta X_{h}^{j}\right), \tag{2}$$

where $X_h^j = \int_{i\in\Omega} z_{hi} q_{hi}^j di$ is the total individual consumption of the differentiated goods measured in units of utility in product category h. Define $P_{hi}^j = p_{hi}^j / z_{hi}$ as the quality-adjusted price of variety i in country j. By transforming Equation (2), the physical demand for variety i is given by

$$Q_{hi}^{j} \equiv L^{j} q_{hi}^{j} = \frac{L^{j}}{\gamma z_{hi}}\left(P_{h,max}^{j} - P_{hi}^{j}\right), \tag{3}$$

where L^j is the mass of consumers in country j and P_{max}^j is the ceiling of the quality-adjusted price below which $q_i^j > 0$ holds. The price ceiling is calculated as

$$P_{h,max}^{j} \equiv \frac{\gamma\alpha + \eta N_h^j \bar{P}_h^j}{\gamma + \eta N_h^j}, \tag{4}$$

where N^j is the measure of the consumed variety of the same product category and $\bar{P}_h^j = (1/N_h^j)\int_{i\in\Omega} P_{hi}^j di$ is the average quality-adjusted price in country j.

On the supply side, labor is the only factor of production. We assume both countries produce the numéraire good and free trade prevails in that sector. In producing the numéraire good, the two countries utilize the same production technology, and one unit of labor produces one unit of the good. These assumptions ensure that wages in the two countries become identical and unity. In producing a variety of non-numéraire, product category h in country j, each firm must pay a fixed entry fee, f_h^j, and draws its marginal processing cost, c, from a distribution denoted by $G(c)$. Firm i's profit earned in country j is given by

$$\pi_{hi}^{j} = \left(\frac{p_{hi}^{j}}{\tau_h^j} - c\right) Q_{hi}^{j}, \tag{5}$$

where $\tau_h^j \geq 1$ is the one plus applied, ad valorem tariff on the imports in country j of product h, where $\tau_h^j = 1$ holds if variety i is sold domestically.

By substituting $q_{hi}^j = Q_{hi}^j / L^j$ into Equation (1) and using Equation (4) and the budget constraint, the indirect utility of function takes the following form:

$$U^{j} = I^{j} + \sum_{h=1}^{M}\left[\frac{1}{2}\left(\eta + \frac{\gamma}{N_h^j}\right)^{-1}\left(\alpha - \bar{P}_h^j\right)^2 + \frac{N_h^j}{2\gamma}\left(\sigma_h^j\right)^2\right], \tag{6}$$

where $\sigma_h^j \equiv \sqrt{\int_{i\in\Omega}(P_{hi}^j - \bar{P}_h^j)^2 / N_h^j}$ represents the standard deviation of prices of product h in country j. The consumer's utility is, ceteris paribus, decreasing in the average quality-adjusted price, increasing in the number of varieties in each product category, and increasing in the variance of prices.[12] These properties of the indirect utility function are the same as those of Melitz and Ottaviano (2008), although their price in the utility is the quality-adjusted price in our model.

3.2. Price, Quantity, and Quality of Each Variety

Following Baldwin and Harrigan (2011) and Johnson (2012), the quality of each variety depends on the producing firm's marginal cost, and it is given by $z_{hi} = c^{1+\theta}$, where $1+\theta$ is the extent to which higher marginal costs are associated with higher quality (i.e., quality elasticity) and $\theta \in (-1, +\infty)$.[13]

By maximizing π_{hi}^{j} with respect to p_{hi}^{j}, and by deriving each firm's profit as the function of its marginal cost, $\pi_{h}^{j}(c)$, we obtain the cut-off level of marginal costs at which the profit is equal to zero, $\pi_{h}^{j}(c) = 0$.[14] When a firm producing in country *j* sells the good in country *j*, it is free from the tariff, and the cut-off level is given by $c_{hD}^{j} \equiv (P_{h,max}^{j})^{-\frac{1}{\theta}}$. If a firm producing outside country *j* exports the good to country *j*, it is subject to tariff and the cut-off level is given by $c_{hX}^{j} \equiv \left(\tau_{h}^{j}/P_{h,max}^{j}\right)^{\frac{1}{\theta}} = (\tau_{h}^{j})^{\frac{1}{\theta}} c_{hD}^{j}$.

By using these cut-offs, the export price and export quantity are respectively given by

$$p_{hX}^{j}(c) \equiv \frac{p_{h}^{j}(c)}{\tau_{h}^{j}} = \frac{c^{1+\theta}}{2}\left[\left(c_{hX}^{j}\right)^{-\theta} + c^{-\theta}\right], \tag{7}$$

$$Q_{hX}^{j}(c) = \frac{\tau_{h}^{j} L^{j}}{2\gamma c^{1+\theta}}\left[\left(c_{hX}^{j}\right)^{-\theta} - c^{-\theta}\right]. \tag{8}$$

Then, the profits of the domestic firms and those of the other country's exporting firms earned in country *j* are, respectively, given by

$$\pi_{hD}^{j}(c) = \frac{L^{j}}{4\gamma}\left[\left(c_{hD}^{j}\right)^{-\theta} - c^{-\theta}\right]^{2}, \tag{9}$$

$$\pi_{hX}^{j}(c) = \frac{\tau_{h}^{j} L^{j}}{4\gamma}\left[\left(c_{hX}^{j}\right)^{-\theta} - c^{-\theta}\right]^{2}. \tag{10}$$

The relationship between the profit and the marginal cost depends on the sign of θ, as is

[12] Utility is increasing in the variance of prices because consumers can shift their expenditures towards lower priced varieties within each product category.

[13] Kugler and Verhoogen (2008) empirically found that higher input costs is associated with higher product quality. Others, such as Antoniades (2015), Ludema and Yu (2016), and Fieler et al. (2018), explicitly consider each firm's endogenous choice of quality. However, our product-level data cannot identify firm-level quality differences. Therefore, and as suggested by Baldwin and Harrigan (2011), as long as the variation in firm-specific quality choice depends only on firm-specific draw of production costs, the "power-function approach" of the cost-quality nexus is a reasonable approximation in calculating the average level of quality within each product category.

[14] The detailed calculation of the cutoff is provided in Appendix C.

summarized in the following lemma:

Lemma 1 *A lower marginal cost increases the firm's profit if* $\theta < 0$, *and a higher marginal cost increases the profit if* $\theta > 0$.

When $\theta < 0$ holds, both $\pi^j_{hD}(c)$ and $\pi^j_{hX}(c)$ are decreasing in c, and firms with low marginal costs survive in country j's market. Even though higher product quality comes with higher marginal cost, the cost-increasing effect dominates the quality-enhancing effect, and lower c corresponds to higher profits. In this case, the market equilibrium is characterized by *productivity sorting*, where a firm with lower c charges lower prices, has a higher market share, earns higher profits, and is more likely to survive. When $\theta > 0$ holds, however, the profits are increasing in c. In this case, higher c leads to an exponential increase in quality, and *quality sorting* occurs. Namely, a firm with higher marginal cost charges a higher price and a lower quality-adjusted price in the market, earns higher profits, and is more likely to survive in the market.

The effects of changes in the cut-off level of marginal cost on the price and profits also depend on the sign of θ, as summarized in the following lemma:

Lemma 2 *An increase in the cut-off level of the marginal cost in country j increases prices and the firms' profits earned in country j under productivity sorting* ($\theta < 0$)*, but it decreases them under quality sorting* ($\theta > 0$)*.*

Under productivity sorting, the cost effect dominates the quality effect, and an increase in the cut-off level means that firms with higher marginal costs can survive in the market. Because these new surviving-firms have higher marginal costs than the original surviving firms, they set higher prices. In response, the original surviving firms raise prices and their profits increase. Under quality sorting, however, the quality effect is large enough to outweigh the cost effect, and firms with higher c are more competitive in the product market. In this case, an increase in the cut-off level means more competitive firms remain in the market. These firms lower their prices, and profits decrease for the original surviving firm. Below, we subsequently examine tariff pass-through under productivity sorting and quality sorting.

3.3. Tariff Pass-Through under Productivity Sorting

Let us first investigate the case with $\theta < 0$, where both $\pi^j_{hD}(c)$ and $\pi^j_{hX}(c)$ are decreasing in c. In this case, firms in country j with $c < c^j_{hD}$ survive in the domestic market, whereas those with $c < c^j_{hX}$ who produce outside country j export their good to country j. We assume that a cost draw follows a Pareto distribution and is given by $G(c) = (c/c^M)^k$ with support on $c \in [0, c_M]$, where k (≥ 1) is the shape parameter. The corresponding density function is $G'(c) = kc^{k-1}/(c^M)^k$. According to this distribution function, there are fewer low-cost firms than high-cost firms.

The free-entry principle implies that the ex-ante expected profits of product category h upon entry in country j should be equal to f_h^j. For instance, the expected profits from locating and producing in country A consist of the expected profit from the domestic supply, $\pi_{hD}^A(c)$, and the expected profit from exporting to country B, $\pi_X^B(c)$. Given the cut-off levels of firm entry, the two countries' free-entry conditions are given by

$$\int_0^{c_{hD}^A} \pi_{hD}^A(c)dG(c) + \int_0^{c_{hX}^B} \pi_{hX}^B(c)dG(c) = f_h^A, \tag{11}$$

$$\int_0^{c_{hD}^B} \pi_{hD}^B(c)dG(c) + \int_0^{c_{hX}^A} \pi_{hX}^A(c)dG(c) = f_h^B. \tag{12}$$

By using Equations (9) and (10), the equilibrium cut-off level, $\tilde{c}_{hD}^j$ $(j \in \{A, B\})$, is determined by solving Equations (11) and (12):

$$\tilde{c}_{hD}^j = \left[\frac{\{f_h^j - \rho_h^l f_h^l\}\Phi}{\{1 - \rho_h^j \rho_h^l\}L^j}\right]^{\frac{1}{k-2\theta}} \quad (l \in \{A, B\}, l \neq j), \tag{13}$$

where $\rho_h^j \equiv (\tau_h^j)^{\frac{k-\theta}{\theta}} < 1$ and $\Phi \equiv 2\gamma(k-\theta)(k-2\theta)c_M^k/\theta^2 > 0$. Because $\theta < 0$, ρ^j corresponds to Melitz and Ottaviano (2008)'s "freeness" of trade and is decreasing in τ^j. To ensure that $\tilde{c}_{hD}^j > 0$ holds, we assume $f_h^j - \rho_h^l f_h^l > 0$. The cost cut-off for exporting to country j becomes $\tilde{c}_{hX}^j = (\tau_h^j)^{\frac{1}{\theta}} \tilde{c}_{hD}^j$.

The right-hand side of Figure 1 depicts the determination of the cut-off level in the two countries. The combination of cut-off levels that satisfies the free-entry conditions of both country A and country B are, respectively, depicted as the aa curve and bb curve. These curves' downward slope can be explained as follows. A lower marginal cost cut-off in the other country implies, on average, lower expected profits from exporting because more productive firms operate in that country. Furthermore, it discourages the domestic firm's entry and makes the domestic market less competitive, thereby increasing the domestic country's cut-off level because the less productive firm can make a positive profit. The intersection of the two curves determines the equilibrium cut-offs. Because more entries correspond to a lower cut-off of the marginal cost, the number of varieties available in country j, $\tilde{N}^j$ is decreasing in $\tilde{c}_{hD}^j$, as depicted in the left-hand side of Figure 1 for country B.[15]

=== Figure 1 ===

In the short run, a tariff decrease simply hurts domestic firms in country B and

[15] By Equation (8) and given the distribution, $G(c)$, the average quality-adjusted price of good h in country j is calculated as $\bar{P}_h^j = (2k-\theta)(\tilde{c}_{hD}^j)^{-\theta}/\{2(k-\theta)\}$. By substituting this price into Equation (4), the number of varieties sold in country j is given by $\tilde{N}_h^j = -2\gamma(k-\theta)\left[\alpha - (\tilde{c}_D^j)^{-\theta}\right]/\theta\eta(\tilde{c}_D^j)^{-\theta}$.

benefits firms in country A. In the long-run, however, tariff decreases change the number of entrants in each country. Let us now examine how trade liberalization affects the cut-off level of marginal costs. According to Equation (13) and $\tilde{c}^j_{hX} = (\tau^j_h)^{\frac{1}{\theta}}\tilde{c}^j_{hD}$, a decrease in τ^j increases both $\tilde{c}^j_{hD}$ and $\tilde{c}^j_{hX}$ with $\theta < 0$. Suppose that country B reduces its tariff. Trade liberalization then increases the expected profit from entry in country A. The free-entry conditions then raise the number of the entrants in country A and decrease $\tilde{c}^A_{hD}$, given the level of $\tilde{c}^B_{hD}$. This effect is illustrated in Figure 2, where the aa curve shifts inside to the $a'a$ curve. Because more productive firms export to country B on average, trade liberalization decreases the expected profit in country B. Therefore, it reduces the number of the entrants in country B and increases $\tilde{c}^B_{hD}$. This implies that less productive producers enter country B. This is the sorting effect of trade liberalization.

=== Figure 2 ===

Furthermore, because the decrease in the number of the domestic varieties in the liberalization country exceeds the increase in the number of the foreign varieties, trade liberalization decreases the number of varieties consumed in country B, as is depicted in the left-side of Figure 2, while it increases the number of entrants in country A. This is the firm-delocation effect of trade liberalization.

Now, we calculate the price and quality effects of a tariff reduction. Because our trade data are product-level rather than firm-level, we need to calculate the average export price of each product category in order to examine tariff pass-through. Specifically, our empirical analysis uses the unit value of each product category as the average export price. Total export values are given by $TV^j_{hX} = \int_0^{\tilde{c}^j_{hX}} p^j_{hX}(c)Q^j_{hX}(c)dG(c)$, and the total export quantity is given by $TQ^j_{hX} = \int_0^{\tilde{c}^j_{hX}} Q^j_{hX}(c)dG(c)$. Then, average export prices defined by unit values become

$$\bar{p}^j_{hX} \equiv \frac{TV^j_{hX}}{TQ^j_{hX}} = \frac{(k-2\theta-1)(k-\theta-1)}{k(k-2\theta)}\tilde{c}^j_{hX}. \tag{14}$$

We should also calculate the average quality-adjusted prices, which are defined as the average export prices divided by average quality of exported products. The average quality is given by

$$\bar{z}^j_{hX} = \frac{1}{G(\tilde{c}^j_{hX})}\int_0^{\tilde{c}^j_{hX}} c^{1+\theta}dG(c) = \frac{k}{k+\theta+1}\left(\tilde{c}^j_{hX}\right)^{1+\theta}. \tag{15}$$

Then, the average quality-adjusted export price is given by

$$\bar{P}^j_{hX} \equiv \frac{\bar{p}^j_{hX}}{\bar{z}^j_{hX}} = \frac{(k-2\theta-1)\{k^2-(1+\theta)^2\}}{k^2(k-2\theta)}\left(\tilde{c}^j_{hX}\right)^{-\theta}. \tag{16}$$

By differentiating Equation (14) with respect to τ_h^j, we obtain the tariff elasticity of export price as

$$\frac{d\ln\bar{p}_{hX}^j}{d\ln\tau_h^j}=\frac{\left(1-\rho_h^j\rho_h^l\right)+\rho_h^l(k-\theta)}{\theta\left(1-\rho_h^j\rho_h^l\right)(k-2\theta)}\equiv\varepsilon_{hX}^j<0. \tag{17}$$

By Equation (15), the tariff elasticity of export quality is given by

$$\frac{d\ln\bar{z}_{hX}^j}{d\ln\tau_h^j}=(1+\theta)\varepsilon_{hX}^j<0, \tag{18}$$

and the tariff elasticity of the quality-adjusted export price becomes

$$\frac{d\ln\bar{P}_{hX}^j}{d\ln\tau_h^j}=-\theta\varepsilon_{hX}^j<0. \tag{19}$$

Because of the firm-delocation effect described above, trade liberalization decreases the number of varieties in the domestic market, which softens market competition and increases the average quality-adjusted price in the domestic country. Furthermore, less productive producers survive in the liberalizing country, and this sorting effect makes the market competition softer and increases average quality-adjusted prices in the liberalizing country. Such productivity sorting also increases the product's average quality because firms with higher marginal costs produce higher-quality varieties. Therefore, trade liberalization also increases the average gross price. The following proposition summarizes these effects:

Proposition 1 *Under productivity sorting, a decrease in the tariff in the destination country increases the average gross price, average quality, and average quality-adjusted price of exported products.*

The direction of the change in quality-adjusted price is consistent with our empirical result. The directions of changes in (gross) export price and export quality, however, are opposite to our empirical results. This indicates that our productivity sorting model is inappropriate to explain the product-level tariff pass-through of worldwide trade.

3.4. Tariff Pass-Through under Quality Sorting

Let us next investigate the case with $\theta>0$, where both $\pi_{hD}^j(c)$ and $\pi_{hX}^j(c)$ are increasing in c. In this case, we will observe the quality sorting of firms. Contrary to the productivity-sorting case, firms with $c>c_{hD}^j$ survive in the domestic market of country *j*, and firms with $c>c_{hX}^j$ export to country *j*. Here, a Pareto distribution of firm's cost draws is given by $G(c)=1-(c_0/c)^k$, such that there are fewer high-quality firms than low-quality firms. The corresponding density function is $G'(c)=kc_0^k/c^{k+1}$.

The two countries' free-entry conditions are given by

$$\int_{c_{hD}^{A}}^{+\infty} \pi_{hD}^{A}(c)dG(c) + \int_{c_{hX}^{B}}^{+\infty} \pi_{hX}^{B}(c)dG(c) = f_h^A, \tag{20}$$

$$\int_{c_{hD}^{B}}^{+\infty} \pi_{hD}^{B}(c)dG(c) + \int_{c_{hX}^{A}}^{+\infty} \pi_{hX}^{A}(c)dG(c) = f_h^B. \tag{21}$$

The right-hand side of Figure 3 depicts these free-entry conditions. As in Figure 1, the aa curve represents the free-entry condition in country A, and the bb curve represents that in country B. Their downward slope reflects the fact that a higher cut-off level in the foreign country means that the firms producing higher-quality good operate in that country, diminishing the expected profits from exporting and discouraging the domestic firm's entry. The reduced entry makes the domestic market less competitive, which decreases the cut-off level of the domestic country because lower-quality firms can make positive profits.

=== Figure 3 ===

By solving Equations (20) and (21), the cut-off level of the domestic survival is given by

$$\tilde{c}_{hD}^{j} = \left[\frac{\{1 - \lambda_h^j \lambda_h^l\}\Psi L^j}{f_h^j - \lambda_h^l f_h^l}\right]^{\frac{1}{k+2\theta}} \quad (l \in \{A, B\}, l \neq j), \tag{22}$$

where $\lambda_h^j \equiv \left(\tau_h^j\right)^{-\frac{k+\theta}{\theta}} < 1$ and $\Psi \equiv \theta^2 c_0^k / [2\gamma(k+\theta)(k+2\theta) f_E] > 0$. We assume $f_h^j - \lambda^l f_h^l > 0$ to ensure that $\tilde{c}_{hD}^{j} > 0$ holds. The cost cut-off for exporting to country j becomes $\tilde{c}_{hX}^{j} = (\tau_h^j)^{\frac{1}{\theta}} \tilde{c}_{hD}^{j}$. The number of varieties sold in country j is given by

$$\tilde{N}_h^j = \frac{2\gamma(k+\theta)\left[\alpha - \left(\tilde{c}_{hD}^{j}\right)^{-\theta}\right]}{\theta\eta\left(\tilde{c}_{hD}^{j}\right)^{-\theta}}. \tag{23}$$

As is depicted in the left-hand side of Figure 3, an increase in $\tilde{c}_{hD}^{j}$ increases $\tilde{N}_h^j$. Under quality sorting, a higher cut-off of the marginal cost (i.e., a higher cut-off quality) corresponds to more entries, and thus the number of variety available in country j, $\tilde{N}^j$, is increasing in $\tilde{c}_{hD}^{j}$.

Let us consider the effect of trade liberalization. For instance, a reduction to the import tariff in country B shifts the aa curve outside to the $a'a'$ curve in Figure 4 because it increases the expected profits from producing in country A and the increased entry increases $\tilde{c}_{hD}^{A}$ given $\tilde{c}_{hD}^{B}$. As a result, trade liberalization decreases $\tilde{c}_{hD}^{B}$ and decreases the number of varieties consumed in the liberalizing country (firm-delocation effect). A decrease in $\tilde{c}_{hD}^{B}$ comes with a decrease in $\tilde{c}_{hX}^{B}$, which decreases the average cost of firms exporting to country B. Because the former effect increases the average quality-adjusted price whereas the latter effect decreases it, the overall effect is ambiguous.

=== Figure 4 ===

With regard to the average quality, because a reduction in τ^j lowers $\tilde{c}_{hD}^{j}$ and thereby decreases $\tilde{c}^j_{hX}$, relatively lower-cost, lower-quality firms survive in the liberalizing country. Therefore, the average quality decreases with a tariff reduction. The negative effect of trade liberalization on average quality is in contrast to the positive effect of trade liberalization on average quality under productivity sorting.

Because trade liberalization decreases the average quality, it may decrease the average gross price of exported products, even if the average quality-adjusted price increases. The following analysis shows that the quality effect is large enough to derive the positive correlation between tariffs and average gross trade prices (i.e., a Lerner paradox). The total export values are given by $TV^j_{hX} = \int_{\tilde{c}^j_{hX}}^{+\infty} p^j_{hX}(c)Q^j_{hX}(c)dG(c)$, and the total export quantity is by $TQ^j_{hX} = \int_{\tilde{c}^j_{hX}}^{+\infty} Q^j_{hX}(c)dG(c)$. Then, the average unit value of exports becomes

$$\bar{p}^j_{hX} \equiv \frac{TV^j_{hX}}{TQ^j_{hX}} = \frac{(k+2\theta+1)(k+\theta+1)}{k(k+2\theta)}\tilde{c}^j_{hX}. \tag{24}$$

The average quality and quality-adjusted unit value of exports are respectively given by

$$\bar{z}^j_{hX} = \frac{1}{1-G(\tilde{c}^j_{hX})}\int_{\tilde{c}^j_{hX}}^{+\infty} c^{1+\theta}dG(c) = \frac{k}{k-\theta-1}\left(\tilde{c}^j_{hX}\right)^{1+\theta}, \tag{25}$$

$$\bar{P}^j_{hX} \equiv \frac{\bar{p}^j_{hX}}{\bar{z}^j_{hX}} = \frac{(k+2\theta+1)\{k^2-(1+\theta)^2\}}{k^2(k+2\theta)}\left(\tilde{c}^j_{hX}\right)^{-\theta}. \tag{26}$$

We assume $k > 1+\theta$ holds to ensure that the average quality is positive.

By differentiating Equations (31), (32), and (33) with respect to the destination's tariff, we have

$$\frac{d\ln\bar{p}^j_{hX}}{d\ln\tau^j_h} = \frac{(k+\theta)+\left(1-\lambda^j_h\lambda^l_h\right)\theta}{\theta\left(1-\lambda^j_h\lambda^l_h\right)(k+2\theta)} \equiv \epsilon^j_{hX} > 0, \tag{27}$$

$$\frac{d\ln\bar{z}^j_{hX}}{d\ln\tau^j_h} = (1+\theta)\epsilon^j_{hX} > 0, \tag{28}$$

$$\frac{d\ln\bar{P}^j_{hX}}{d\ln\tau^j_h} = -\theta\epsilon^j_{hX} < 0. \tag{29}$$

These results are consistent with our empirical results, as the following proposition summarizes:

Proposition 2 *Under quality sorting, a decrease in tariff in the destination country decreases the average gross price and average quality of exported products, whereas it increases the average quality-adjusted price of exported products.*

A positive effect from the tariff on the gross export price implies that the quality sorting mechanism of exporters in our model explains the presence of the Lerner paradox observed in our empirical analysis. Furthermore, if we calculate the tariff elasticity of quality-adjusted consumer price of exports, we have

$$\frac{d\ln(\tau_h^j\,\bar{P}_{hX}^j)}{d\ln\tau_h^j} = -\frac{\lambda_h^j\lambda_h^l(k+\theta)}{\left(1-\lambda_h^j\lambda_h^l\right)(k+2\theta)} < 0. \tag{30}$$

This means that a tariff decrease also increases the quality-adjusted consumer price in the importing country. Therefore, we can also explain the Metzler paradox for the quality-adjusted price observed in the empirical results.

Bagwell and Staiger (2012) and Bagwell and Lee (2015) suggested that market competition in imperfectly competitive environments with variable markups generates firm-delocation effects, which are driving forces behind the emergence of a Metzler paradox for the average quality-adjusted consumer price. Firm-delocation effects, however, cannot explain a Lerner paradox for gross trade prices. To show the presence of Lerner paradox, the model needs to incorporate a quality-sorting mechanism of Baldwin and Harrigan (2011) or Johnson (2012), where high-cost, high-quality firms are more competitive and more likely to be exporters. Our model is a hybrid of a firm-delocation model and quality-sorting model with heterogeneous firms, which enables us to explain the effects of trade liberalization at the product-level and export prices in worldwide trade. In other words, the worldwide product trade is characterized by price competition under variable markups and quality competition under quality sorting. The resulting entry and exit of firms in both export and domestic markets lead to the concurrence of Lerner and Metzler paradoxes.

3.5. Welfare Effect of Trade Liberalization under Quality Sorting

We have shown that our quality sorting model is consistent with the empirical results. Here, we discuss whether unilateral trade liberalization that generates a Lerner paradox for the average gross price and a Metzler paradox for the average quality-adjusted price improves the welfare of the liberalizing country.

By Equation (6), the consumer's utility is decreasing with the average quality-adjusted price, increasing with the number of varieties, and increasing with the variance of prices. The average quality-adjusted price under quality sorting is calculated as

$$\bar{P}_h^j = \frac{2k+\theta}{2(k+\theta)}\left(\tilde{c}_{hD}^j\right)^{-\theta}, \tag{31}$$

which is decreasing in $\tilde{c}_{hD}^j$. The variance of quality-adjusted prices is given by

$$\left(\tilde{\sigma}_h^j\right)^2 = \frac{k\theta^2}{4(k+\theta)^2(k+2\theta)}\left(\tilde{c}_{hD}^j\right)^{-2\theta}, \tag{32}$$

which is decreasing in $\tilde{c}_{hD}^j$. By Equation (30), the number of varieties in country j is increasing in $\tilde{c}_{hD}^j$.

Under quality sorting, high-cost firms are more competitive because they produce high-quality products, and the positive quality effect outweighs the negative effect higher marginal costs. Hence, higher-cost firms set lower quality-adjusted prices, as is implied by Equation (30). Because trade liberalization in country j decreases $\tilde{c}_D^j$, Equation (23) implies that trade liberalization also reduces the number of varieties sold in that country.

The firm-delocation effect under quality sorting makes the market less competitive, and average quality-adjusted prices increase with trade liberalization. A reduction in the number of varieties and a rise in quality-adjusted prices worsen the consumer's utility in the importing country. By Equation (32), however, trade liberalization increases the variance of quality-adjusted prices, which improves the consumer's utility. By substituting Equations (23), (31), and (32) into Equation (6), consumer utility is represented as a function of $\tilde{c}_{hD}^j$:

$$\widetilde{U}^j = I^j + \frac{1}{2\eta}\sum_{h=1}^{M}\left[\left\{\alpha - \left(\tilde{c}_{hD}^j\right)^{-\theta}\right\}\left\{\alpha - \frac{k+\theta}{k+2\theta}\left(\tilde{c}_{hD}^j\right)^{-\theta}\right\}\right]. \tag{33}$$

Because $\widetilde{U}^j$ is increasing in $\tilde{c}_{hD}^j$, the negative effects from an increase in quality-adjusted prices and decrease in varieties dominate the positive effect from the increase in variance of quality-adjusted prices. As a result, trade liberalization hurts domestic consumers.

Proposition 3 *Even though a tariff reduction decreases the gross trade price, it worsens the welfare of liberalizing country because it substantially decreases the average quality, increases quality-adjusted prices, and decreases the number of varieties.*

This proposition suggests that a unilateral tariff reduction should be accompanied by some additional policy reforms to ensure that the consumer benefits from trade liberalization. One such possible policy is to reduce the cost of entry. This would enhance competition in the liberalizing country and mitigate the increases in the quality-adjusted prices caused by the firm-delocation effect of trade liberalization. Note that Equation (22) suggests that a decline in f_h^j increases $\tilde{c}_{hD}^j$, implying the increased entries of firms intensifies competition in the domestic country, thereby inducing relatively low-quality firms to exit. A reduction in the cost of entry thus benefits domestic consumers. Therefore, if a competition policy that enhances domestic entry is enacted to accompany trade liberalization, such a policy will mitigate the negative effect of trade liberalization.

4. Concluding Remarks

This paper started by quantifying the worldwide tariff pass-through, i.e., the impact of tariff reductions on trade prices. We found that a 1% reduction of (one plus) tariffs decreases trade prices by 0.1%, i.e., a negative tariff pass-through (Lerner paradox). To better understand the mechanism underlying this result, we next decomposed trade prices into product quality and quality-adjusted trade prices. As a result, we found that a 1% reduction of (one-plus) tariff rates decreases product quality by 1.2% and increases quality-adjusted trade prices by 1.1% (Metzler paradox). To formalize these empirical findings, we constructed a theoretical model that demonstrates the mechanism underlying these empirical results. We suggested that a firm-delocation mechanism under variable markups and a quality-sorting mechanism are the driving forces behind these empirical findings.

Our theoretical model indicates that although a lower tariff decreases the average consumer price of imported products, it comes with even lower quality of these products and thereby increases quality-adjusted consumer prices. The number of varieties of goods also decreases with trade liberalization. We show that a simple reform which unilaterally reduces import tariff hurts domestic consumers. To ensure that consumers benefit from trade liberalization, a reduction in the destination country's tariff should be accompanied by additional policy reforms that prevent increases in quality-adjusted prices or that mitigate the drop in average quality of exported products.

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Table 1. Global Average of Tariff Pass-through

	(I)	(II)	(III)
ln (1 + Tariff)	0.041***	-0.033***	0.084***
	[0.004]	[0.005]	[0.010]
Exporter-Importer-Product	YES	YES	YES
Exporter-Importer-Year	YES	YES	YES
Exporter-Product-Year	NO	YES	YES
Importer-Product-Year	NO	NO	YES
Number of obs	57,781,720	57,781,720	57,781,720
Adj R-squared	0.7499	0.7588	0.7749

Notes: The dependent variable is a log of trade prices. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parentheses contain the robust standard error.

Table 2. Decomposition into Quality-adjusted Prices and Quality

	(I)	(II)	(III)
Quality-adjusted prices			
ln (1 + Tariff)	-1.290***	-1.101***	-1.105***
	[0.006]	[0.006]	[0.013]
Exporter-Importer-Product	YES	YES	YES
Exporter-Importer-Year	YES	YES	YES
Exporter-Product-Year	NO	YES	YES
Importer-Product-Year	NO	NO	YES
Number of obs	57,781,720	57,781,720	57,781,720
Adj R-squared	0.9617	0.9639	0.972
Quality			
ln (1 + Tariff)	1.332***	1.067***	1.189***
	[0.007]	[0.007]	[0.016]
Exporter-Importer-Product	YES	YES	YES
Exporter-Importer-Year	YES	YES	YES
Exporter-Product-Year	NO	YES	YES
Importer-Product-Year	NO	NO	YES
Number of obs	57,781,720	57,781,720	57,781,720
Adj R-squared	0.9285	0.932	0.9425

Notes: ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parentheses contain the robust standard error.

Figure 1. Equilibrium cut-offs under productivity sorting

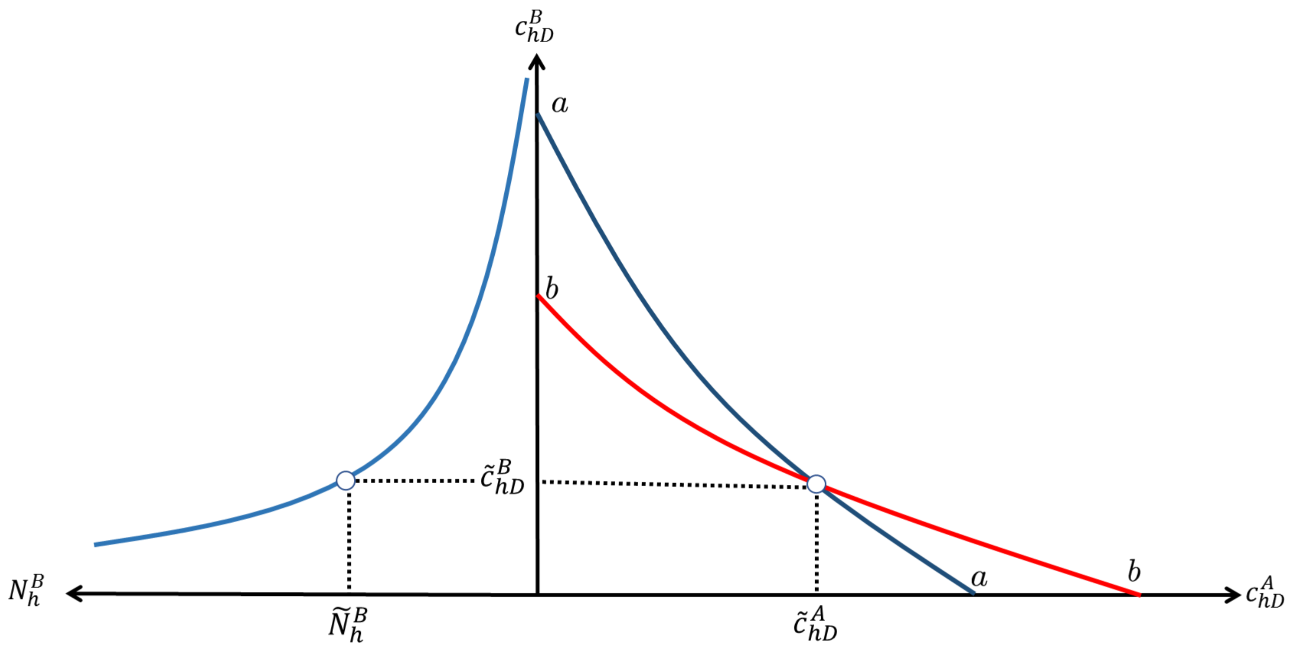


Figure 2. Effect of trade liberalization on country B under productivity sorting

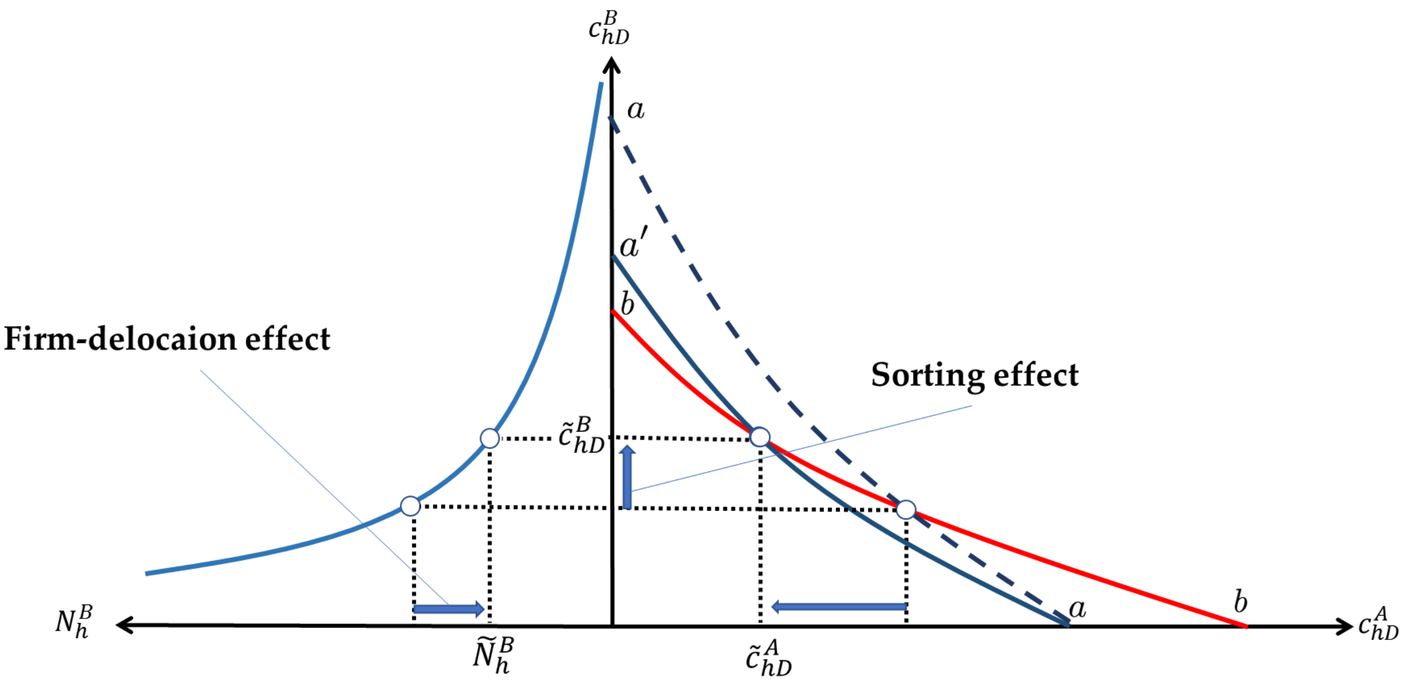


Figure 3. Equilibrium cut-offs under quality sorting

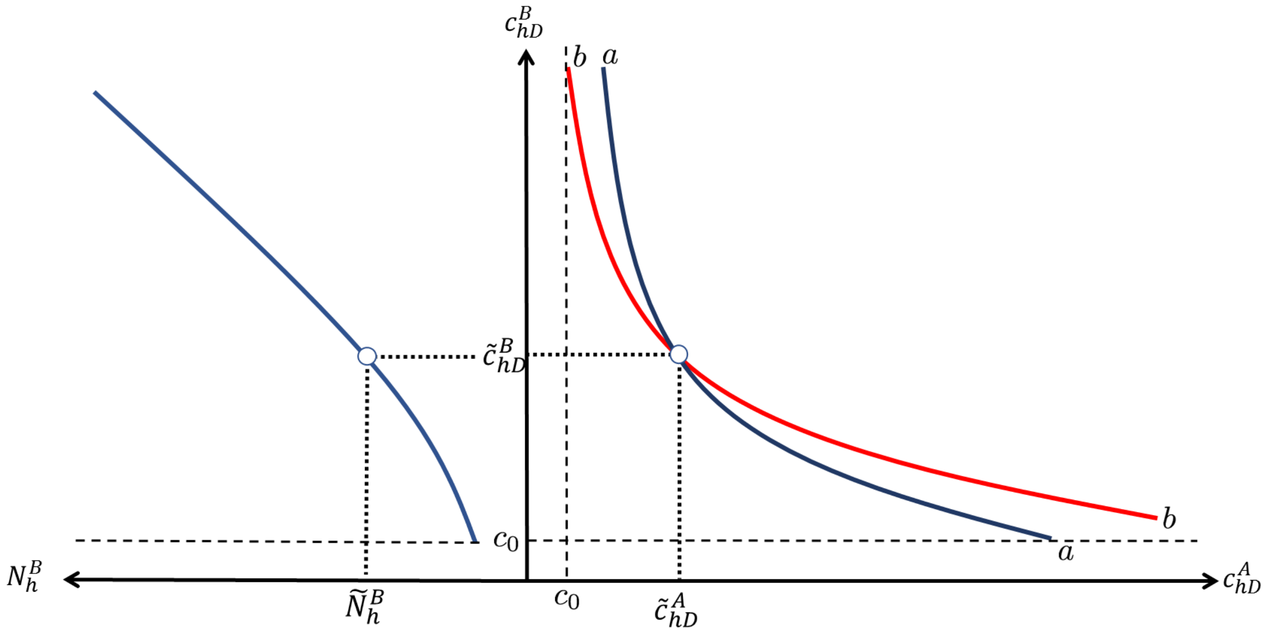
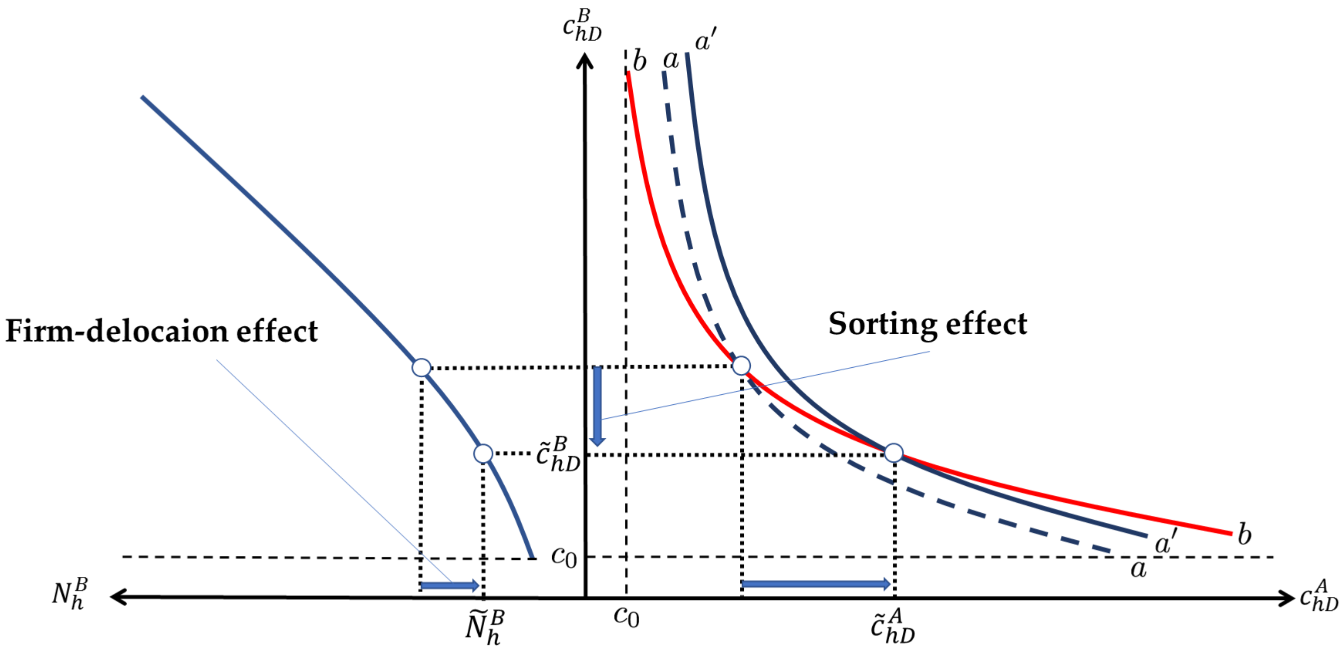


Figure 4. Effect of trade liberalization on country B under quality sorting



Appendix A. Sample Countries

A1. Importing Countries (70 Countries)

ARG, AUS, BLZ, BRA, CAF, CAN, CHE, CHL, CHN, COL, CYP, DEU, DMA, DNK, DZA, ECU, EGY, ESP, FIN, FRA, GAB, GBR, GRC, GRD, GTM, HKG, HND, HRV, HUN, IDN, IND, IRL, ISL, ITA, JOR, JPN, KNA, KOR, LKA, LTU, LVA, MAC, MAR, MDG, MEX, MKD, MUS, MWI, MYS, NIC, NLD, NOR, NZL, OMN, PER, POL, PRT, SAU, SLV, SVK, SVN, SWE, TGO, THA, TUN, TUR, URY, USA, VCT, VEN

A2. Exporting Countries (172 Countries)

AFG, AGO, ALB, ARE, ARG, ARM, ATG, AUS, AUT, AZE, BDI, BEL, BEN, BFA, BGD, BGR, BHR, BIH, BLR, BLZ, BMU, BRA, BRB, BRN, BTN, BWA, CAF, CAN, CHE, CHL, CHN, CIV, CMR, COG, COL, COM, CPV, CRI, CUB, CYP, CZE, DEU, DJI, DMA, DNK, DOM, DZA, ECU, EGY, ERI, ESP, EST, ETH, FIN, FJI, FRA, GAB, GBR, GEO, GHA, GIN, GMB, GNB, GNQ, GRC, GRD, GTM, GUY, HKG, HND, HRV, HTI, HUN, IDN, IND, IRL, IRN, ISL, ISR, ITA, JAM, JOR, JPN, KAZ, KEN, KGZ, KHM, KNA, KOR, KWT, LAO, LBN, LBY, LCA, LKA, LSO, LTU, LUX, LVA, MAC, MAR, MDA, MDG, MDV, MEX, MKD, MLI, MLT, MMR, MNG, MOZ, MRT, MUS, MWI, MYS, NAM, NER, NGA, NIC, NLD, NOR, NPL, NZL, OMN, PAK, PAN, PER, PHL, PLW, PNG, POL, PRT, PRY, QAT, RUS, RWA, SAU, SDN, SEN, SGP, SLB, SLV, SUR, SVK, SVN, SWE, SWZ, SYC, SYR, TCD, TGO, THA, TJK, TKM, TON, TTO, TUN, TUR, TZA, UGA, UKR, URY, USA, UZB, VCT, VEN, VNM, VUT, YEM, ZAF, ZMB, ZWE

Appendix B. Other Tables

This appendix presents our robustness checks. First, the basic statistics are provided in Table B1. Second, we start with the estimation of our model on gross prices for some subsamples. A set of fixed effects is the same as that in column (III) in Table 1. Based on the conservative classification in Rauch (1999), we estimate for differentiated products and nondifferentiated products separately. The results are shown in Table B2. The coefficients are significantly positive for both types of products although the absolute magnitude is slightly larger in the case of nondifferentiated products.

We also examine the lagged effects of tariffs. A set of fixed effects is the same as that in column (III) in Table 1. In column (I) in Table B3, we introduce a one-year lagged tariff variable. Both concurrent and one-year lagged variables have significantly positive coefficients; the coefficient magnitude is larger in the lagged variable. In column (II), we also introduce three-year lagged tariff variable. Although the concurrent and three-year lagged variables have significantly positive coefficients, the coefficient for the one-year lagged variable turns out to be insignificant. Column (III) further introduces a five-year lagged variable and shows that only the coefficients for three-year and five-year lagged variables are significantly positive. In sum, although the significant coefficients differ by specifications, a sign with statistical significance is always positive.

Third, we separately estimate similar models for quality-adjusted prices and quality. A set of fixed effects is the same as that in column (III) in Table 2. In Table B4, we estimate the model for differentiated and nondifferentiated products separately. Both cases show a negatively significant coefficient for quality-adjusted prices and a positively significant coefficient for quality. In addition, for both quality-adjusted prices and quality, the absolute magnitude is larger for differentiated products than nondifferentiated products.

In Table B5, we introduce lagged tariff variables. The results of the concurrent tariffs are unchanged from those in Table 2 for both quality-adjusted prices and quality equations. The coefficients are negative for quality-adjusted prices but positive for quality. However, almost all lagged variables have the opposite sign to that on the concurrent tariff variable. This implies that one year after a tariff reduction, the reduction has had the effect of moving quality-adjusted prices and quality back to their original level. Nevertheless, the sum of the coefficients for one- and more-year lagged variables is much smaller than the coefficient for the concurrent tariff variable in terms of absolute value. Therefore, the total effect remains negative for quality-adjusted prices but positive for quality.

Table B1. Basic Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln Gross prices	57,781,720	2.524	1.733	-17.123	18.666
ln Quality-adjusted prices	57,781,720	4.211	5.327	-4.399	29.285
ln Quality	57,781,720	-1.687	5.044	-26.295	5.752
ln (1 + Tariff)	57,781,720	0.050	0.082	0	3.434
* ln Importer's GDP	57,781,720	1.305	2.148	0	88.606
* ln Exporter's GDP per capita	57,781,720	0.481	0.798	0	38.249
L1. ln (1 + Tariff)	50,367,256	0.047	0.080	0	3.434
L3. ln (1 + Tariff)	50,367,256	0.054	0.087	0	3.434
L5. ln (1 + Tariff)	50,367,256	0.062	0.095	0	3.434

Source: Authors' computation.

Table B2. Global Average of Tariff Pass-through: Differentiated versus Nondifferentiated Products

	Differentiated	Non-differentiated
ln (1 + Tariff)	0.063***	0.108***
	[0.012]	[0.018]
Number of obs	41,024,355	16,727,990
Adj R-squared	0.7423	0.7855

Notes: The dependent variable is a log of trade prices. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parentheses contain the robust standard error. In both specifications, we introduce exporter-importer-product, exporter-importer-year, exporter-product-year, and importer-product-year fixed effects.

Table B3. Global Average of Tariff Pass-through: Lagged Effects

	(I)	(II)	(III)
ln (1 + Tariff)	0.035***	0.029**	0.015
	[0.013]	[0.013]	[0.014]
L1. ln (1 + Tariff)	0.068***	0.022	0.023
	[0.013]	[0.014]	[0.014]
L3. ln (1 + Tariff)		0.092***	0.081***
		[0.011]	[0.012]
L5. ln (1 + Tariff)			0.023**
			[0.011]
Number of obs	55,099,219	53,242,877	50,367,256
Adj R-squared	0.7754	0.7769	0.7782

Notes: The dependent variable is a log of trade prices. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parenthesis contain the robust standard error. In all specifications, we introduce exporter-importer-product, exporter-importer-year, exporter-product-year, and importer-product-year fixed effects.

Table B4. Decomposition into Quality-adjusted Prices and Quality: Differentiated versus Nondifferentiated Products

	Differentiated	Non-differentiated
Quality-adjusted prices		
ln (1 + Tariff)	-1.137***	-1.006***
	[0.015]	[0.026]
Number of obs	41,024,355	16,727,990
Adj R-squared	0.9728	0.9682
Quality		
ln (1 + Tariff)	1.200***	1.113***
	[0.019]	[0.031]
Number of obs	41,024,355	16,727,990
Adj R-squared	0.9431	0.9409

Notes: The dependent variable is a log of trade prices. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parenthesis contain the robust standard error. In all specifications, we introduce exporter-importer-product, exporter-importer-year, exporter-product-year, and importer-product-year fixed effects.

Table B5. Decomposition into Quality-adjusted Prices and Quality: Lagged Effects

	(I)	(II)	(III)
Quality-adjusted prices			
ln (1 + Tariff)	-1.233***	-1.234***	-1.230***
	[0.017]	[0.017]	[0.019]
L1. ln (1 + Tariff)	0.172***	0.145***	0.138***
	[0.017]	[0.018]	[0.019]
L3. ln (1 + Tariff)		0.062***	0.063***
		[0.014]	[0.016]
L5. ln (1 + Tariff)			0.002
			[0.014]
Number of obs	55,099,219	53,242,877	50,367,256
Adj R-squared	0.9723	0.9723	0.9723
Quality			
ln (1 + Tariff)	1.269***	1.263***	1.244***
	[0.021]	[0.022]	[0.023]
L1. ln (1 + Tariff)	-0.103***	-0.123***	-0.115***
	[0.021]	[0.023]	[0.024]
L3. ln (1 + Tariff)		0.030*	0.018
		[0.017]	[0.020]
L5. ln (1 + Tariff)			0.022
			[0.017]
Number of obs	55,099,219	53,242,877	50,367,256
Adj R-squared	0.943	0.9431	0.9433

Notes: The dependent variable is a log of trade prices. ***, **, and * indicate 1%, 5%, and 10% significance, respectively. Parentheses contain the robust standard error. In all specifications, we introduce exporter-importer-product, exporter-importer-year, exporter-product-year, and importer-product-year fixed effects.

Appendix C. The Derivation of the Cut-off Level of Marginal Cost

By maximizing π_{hi}^{j} with respect to p_{hi}^{j}, we obtain the profit-maximizing quantity of each variety as

$$Q_{hi}^{j} = \left(p_{hi}^{j} - \tau_{h}^{j} c\right) \frac{L^{j}}{\gamma (z_{hi})^{2}}. \qquad (A1)$$

Combining Equations (3) and (A1), we can represent price and quantity as a function of the firm's marginal cost:

$$p_{h}^{j}(c) = \frac{z_{hi}}{2}\left(P_{h,max}^{j} + \tau_{h}^{j} \frac{c}{z_{hi}}\right) = \frac{c^{1+\theta}}{2}\left(P_{h,max}^{j} + \tau_{h}^{j} c^{-\theta}\right),$$

$$Q_{h}^{j}(c) = \frac{L^{j}}{2\gamma z_{hi}}\left(P_{h,max}^{j} - \tau_{h}^{j} \frac{c}{z_{hi}}\right) = \frac{L^{j}}{2\gamma c^{1+\theta}}\left(P_{h,max}^{j} - \tau_{h}^{j} c^{-\theta}\right).$$

The quality-adjusted price is given by $P^{j}(c) = p^{j}(c)/z_{i}$. The profit of a firm in country j whose marginal cost is c is given by

$$\pi_{h}^{j}(c) = \frac{L^{j}}{4\gamma \tau_{h}^{j}}\left(P_{h,max}^{j} - \tau_{h}^{j} c^{-\theta}\right)^{2}.$$

The cut-off level of the marginal cost is the marginal cost that satisfies $\pi_{h}^{j}(c) = 0$. When the firm sells in the domestic country, $\tau_{h}^{j} = 1$, and the cut-off level is given by $c_{hD}^{j} \equiv \left(P_{h,max}^{j}\right)^{-\frac{1}{\theta}}$. When the firm exports to country j, $\tau_{h}^{j} > 1$ and the cut-off level is given by $c_{hX}^{j} \equiv \left(\tau_{h}^{j}/P_{h,max}^{j}\right)^{\frac{1}{\theta}} = (\tau_{h}^{j})^{\frac{1}{\theta}} c_{hD}^{j}$.