Trade Liberalization, Quality, and Export Prices*

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This Version: August 2013

Abstract

This paper examines how trade liberalization affects unit value export prices and product quality. The paper first documents four stylized facts regarding the effect of trade liberalization on export prices. Then, to explain those stylized facts, the paper extends Melitz's (2003) model of trade with heterogeneous firms by introducing endogenous quality choice and endogenous number of imported varieties as well as endogenous technology upgrading. There are two key predictions. First, given productivity and import decision, a reduction in import tariff induces firms to choose higher quality and to set higher export prices when quality is heterogeneous. However, when quality is homogeneous, a reduction in import tariff induces firms to set lower export prices instead of higher export prices. Second, firms' decisions on import and technology upgrading would amplify the effect of trade liberalization on quality and export prices. The predictions are consistent with the stylized facts based on Chinese data and also robust to various estimation specifications.

*We thank Mary Amiti, Keith Head, Amit Khandelwal, Thomas Chaney, Peter Schott, Michael Waugh, Robert Staiger, Hiroyuki Kasahara, Frédèric Warzynski, Kalina Manova, Ann Harrison, Lorenzo Caliendo, Roberto Samaniego, Ping Lin, Larry Qiu, Jiandong Ju, Edwin Lai, David Cook, Pengfei Wang, the participants of the HKUST Conference in International Economics (HKUST, June 2013), the 9th Annual Meeting of the Asia Pacific Trade Seminars (Nanjing, China, June 2013), the 8th Australasian Trade Workshop (University of Melbourne, March 2013), the Chinese Economists Society Annual Conference (Chengdu, June 2013), the Conference on New Structural Economics (National School of Development, Peking University, October 2012), the 7th Biennial Conference of Hong Kong Economic Association (Lingnan University, December 2012), the Tsinghua International Economics Winter Meeting (Tsinghua University, December 2012), the Hong Kong Universities' Inter-campus Mini Workshops on International Trade and FDI (HKU, March 2013), and of seminars held at HKUST for helpful discussions. All remaining errors are our own.

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1 Introduction

Understanding firms' responses to trade liberalization is one of the major challenges in international trade. A large body of prior literature has devoted to examining the role of imported intermediate inputs in trade liberalization by exploring productivity effect (Pavcnik, 2002; Fernandes, 2007; Amiti and Konings, 2007, among others),[1] or the impacts of tariff change on firms' attributes such as domestic product scope, export value, and export scope (e.g., Goldberg et al., 2010; Bas, 2012; Feng et al., 2012). Despite the prominence of the large literature on imported inputs and trade liberalization, we have surprisingly few studies on the impacts of trade liberalization on firms' export prices.[2] However, it is important to investigate the effect of trade liberalization on export prices and product quality, and to understand the factors that influence the upgrading from the production of low-quality to high-quality products since the production of high-quality goods is often viewed as a pre-condition for export success and, ultimately, for economic development (Amiti and Khandelwal, 2013). Moreover, international specialization is largely across levels of quality within industry rather than across industries (Schott, 2004). This suggests that development is in part about the upgrading of the quality of an existing set of goods, while tariffs can hold back quality upgrading and thus development if they raise the cost of importing high quality inputs. Therefore, this paper aims to provide both theoretical and empirical examination on how trade liberalization affects export prices and product quality, as well as how this relationship depends on firms' decisions on imported varieties and technology upgrading.

Starting with the Chinese firm-product level data, we document four stylized facts regarding the relationship between trade liberalization and export prices for ordinary exporters.[3] Associated with import tariff reductions: First, firms tend to set higher export prices. Second, export prices of differentiated products significantly increase, while the change in export prices of homogeneous goods is nonsignificant and ambiguous. Third, the firms with greater increase in import dependence raise export prices more than those with smaller increase in import dependence. Forth, firms with greater increase in productivity raise export prices more than those with smaller increase in productivity.

To explain those stylized facts under a unified framework, we extend Melitz's (2003) model of trade with heterogeneous firms by introducing endogenous product quality as well as firm decisions on imported varieties and technology upgrading. We focus on the existing two-way traders, namely, firms that both import and export. After the realization of initial productivity, firms decide their imported inputs and whether to upgrade their technology. Given the imported inputs and technology, firms choose optimal prices and quality of their outputs.

[1]Another branch of literature relates imported intermediate inputs and firm TFP or aggregate productivity but does not empirically investigate trade liberalization, such as Kasahara and Rodrigue (2008), Gopinath and Neiman (2011), and Halpern et al. (2011).

[2]De Loecker et al. (2012) is a recent exception using Indian data.

[3]We focus on ordinary exporters in China because under a processing trade regime firms are exempt from import duties (Manova and Yu, 2013; Yu, 2011, among others).

Our model yields the following propositions. First, given productivity and import decision, a reduction in import tariff induces firms to choose higher output quality and to set higher export prices when quality is heterogeneous. However, when quality is homogeneous, a reduction in import tariff induces firms to set lower export prices instead of higher export prices. Second, firms' decisions on imported inputs and technology upgrading amplify the effect of trade liberalization on product quality and export prices. In other words, firms with greater increase in import dependence or productivity raise export prices and quality more than those who are not. Third, tariff reduction induces firms to expand their imported varieties and to adopt technology upgrading. Among the existing exporting firms, less productive firms upgrade technology more than those with higher initial productivity. We present the first two parts in the main text while the derivation of the third part together with its empirical evidence in Appendix.

Next, we test the model predictions using Chinese data. We use Chinese data to test our theory because China presents a good setting to study the impacts of trade liberalization. China's accession to the World Trade Organization (WTO) since December 2001 leads to an important unilateral trade liberalization, associated with a series of significant reductions in China's import tariff and very little corresponding changes in China's trade partners' import barriers against China.[4] To measure import tariff reductions: First, we compute different measures of firm-specific input tariff change. The major reason for constructing firm-specific measures of tariff reductions is the huge variation of tariff change across products within the same industry subsequent to trade liberalization.[5] So it is important to properly measure effective tariff reductions faced by firms when they import different bundles of intermediate inputs, while the average industry tariff measures ignore the tariff variations within the industry (see Section 5.2 in this paper for more detailed discussion). Second, we employ the conventional measures of industry input/output tariffs and show that they also substantiate the predictions of our model. Third, we use instrumental variable estimation to address the potential endogeneity of firm-specific tariff reductions and our results are robust to various estimation methods.

In the main results, we employ the Chinese import tariff data (at the HS6 product level) with a matched Chinese firm-product trade database and report the results of longer-difference estimation based on existing ordinary exporters.[6] Moreover, we conduct various robustness checks. For example, we use processing exporters as comparison group to show that processing firms do not significantly increase export prices and quality, probably because they never pay tariffs to begin with. We also adopt the whole customs data without matching to the manufacturing firm survey to show that our results

[4]Before China joined the WTO, many trade partners had already offered China MFN treatment.

[5]For example, the Input-Output sector, automobile manufacturing (Chinese I-O classification code 37074), includes the HS4 products, "motor cars & vehicles for transporting persons" (HS4 code 8703), and "special purpose motor vehicles" (HS4 code 8705). Within the same I-O sector, some products enjoyed substantial import tariff reduction from 80% in 2001 to 28% in 2006 (e.g., HS8 product "other vehicles", code 87033390), while others remain the same tariff level at 3% between 2001-2006 (e.g., HS8 product "fire fighting vehicles", code 87033390).

[6]Our focus is the response of existing exporters (i.e., exporters that are present both before and after import tariff reductions) to trade liberalization, which is consistent with our empirical investigation based on longer-difference estimation. We do not address entry and exit in this paper.

remain robust to larger samples and thus are not biased towards big firms.[7] In addition, we use the data during the period before the appreciation of Chinese currency to show that export prices indeed rise without currency appreciation. Overall, our empirical results support the model predictions, and highlight the comparison between the heterogeneous- and homogeneous-quality cases.

The main contribution of this paper is that it offers both theory and the empirical evidence on the effect of lower import tariff on quality choice and export prices, adding to the emerging literature on the role of imported inputs in international trade. To the best of our knowledge, this paper provides the first compelling analysis of the impacts of trade liberalization on export prices through the *quality effect* with endogenous firm decisions on imports and technology upgrading. The comparison of testing both the heterogeneous- and homogeneous-quality cases provides evidence to support the mechanism of *quality adjustment*. A key strength of the empirical analysis is that it demonstrates that export prices rise where they should be rising: in goods with greater scope for quality upgrading, i.e., goods with heterogeneous quality. Essentially, homogeneous goods are a placebo: tariff reductions do not lead to higher export prices where they should not. Next, we position our paper in the relevant literature through the following four aspects.

First, this paper is related to the literature examining the effect of imported inputs on productivity and growth, such as Feenstra and Markusen (1994), Muendler (2004), Kasahara and Rodrigue (2008), and Halpern et al. (2011). However, it should be noted that these studies are not related to the effects of trade liberalization.

Second, this paper joins the literature exploring the effect of trade liberalization on productivity, for example, Bernard et al. (2006) for the US and Trefler (2004) for Canada. Except these studies testing data on developed countries, more evidence has been found in developing countries, including Amiti and Konings (2007) for Indonesia, Bustos (2011) for Argentina, Fernandes (2007) for Columbia, Krishna and Mitra (1998) and Topalova and Khandelwal (2011) for India, İşcan (1998) for Mexico, Pavcnik (2002) and Tybout et al. (1991) and for Chile, Schor (2004) for Brazil, among others. These studies find that cheaper imported inputs can raise productivity via learning, variety, and quality effects. Our paper highlights the channel through import variety and quality adjustment, but our focus is changes in export price and quality choice by firms.

Third, this paper also complements the large quality-and-trade literature in confirming the prevalence of product quality heterogeneity at the firm level and the mechanism of quality in the presence of trade liberalization. Our finding of a positive relationship between firm productivity and export prices is consistent with the findings of the literature on product quality.[8] What distinguishes our paper from the literature, however, is that we emphasize that the impacts of trade liberalization on optimal prices act through the optimal adjustment of product quality.

[7] The merged sample mainly contains big firms because the manufacturing survey only applies to above-scale firms.

[8] See Verhoogen (2008), Kugler and Verhoogen (2012), Hallak (2010), Johnson (2012), Hallak and Sivadasan (2011)), Gervais (2013), Manova and Zhang (2012a), Antoniades (2012), among others.

Lastly, this paper complements the empirical literature by affirming the effects of imported intermediate inputs on firms' attributes such as domestic product scope, export value, and export scope, for example, Goldberg et al. (2010) find that the use of imported inputs increases product scope for Indian firms.

The remainder of the paper is organized as follows. Section 2 describes the data and Section 3 documents the stylized facts. To explain the stylized facts, Section 4 presents a trade model with heterogeneous firms, featuring endogenous product quality and highlighting the difference between heterogeneous- and homogeneous-quality goods.[9] Section 5 introduces the strategy of the empirical analysis and the measurement issues. Section 6 presents the empirical results and Section 7 provides some robustness checks. The final section concludes.

2 Data

The Chinese import tariff data are obtained from the WTO website, available as MFN (most-favored nation) applied tariff at the HS 8-digit level and our sample period is 2001-2006.[10] However, China changed HS 8-digit codes in 2002, and the concordance between the old and new HS 8-digit codes (before and after 2002) is not available. To ensure the consistency of the product categorization over time (2001-2006), we choose to adopt HS 6-digit codes maintained by the World Customs Organization (WCO) and use the conversion table from the UN Comtrade to convert the HS 2002 codes into the HS 1996 codes. The average tariff is then computed at HS6 level by using each HS8 tariff line within the same HS6 code. Our empirical analysis for product/variety therefore refers to either HS6 product category or HS6-country combination. The results based on either HS6 product or HS6-country remain similar.

To capture firms' import decisions and pricing behavior, in the main results we use a merged data set based on the two databases: (1) the firm-product-level trade data of each transaction from Chinese customs, and (2) the firm-level production data, collected and maintained by the National Bureau of Statistics of China (NBSC). However, using the Customs trade data alone (without matching to the NBSC data) does not alter our results (see Section 7: Robustness). Next, we briefly describe the data, but leave a more detailed description of sample construction to Appendix A.1.

The main database we use is the Chinese trade data at the transaction level, provided by China's General Administration of Customs. The transaction-level trade data provide information of exporting or importing firm and the product information at the HS-8 level, covering the universe of all Chinese exports and imports in 2001-2006. It records detailed information of each trade transactions, including import and export values, quantities, products, source or destination countries, contact information

[9] We prove the case of the endogenous set of imported varieties as well as the choice of technology upgrading and its propositions in the appendix.

[10] The tariff data are available at http://tariffdata.wto.org/ReportersAndProducts.aspx. We do not include the data in the year of 2000 because the tariff data at HS8 level from the WTO are not available for 2000.

of the firm (e.g., company name, telephone, zip code, contact person), type of enterprises (e.g. state owned, domestic private firms, foreign invested, and joint ventures), and customs regime (e.g. "Processing and Assembling"and "Processing with Imported Materials"). As firms under processing trade regime are not subject to import tariffs, we only include ordinary exporters into our sample.[11] We also exclude all intermediary firms from the customs data, following the similar method as in Ahn et al. (2011) and Tang and Zhang (2012). Due to similar reasons as in tariff data, we aggregate transaction-level data to firm-product-level or firm-product-destination-level trade data at HS6 and HS6-country level. For each product, we use quantities and deflated values to compute unit value export prices for each firm.

To characterize firms' attributes such as TFP and capital intensity, we also use the NBSC firm-level production data from the annual surveys of Chinese manufacturing firms, covering all state-owned enterprises (SOEs), and non-state-owned enterprises with annual sales of at least 5 million RMB (Chinese currency). The NBSC database contains detailed firm-level information of manufacturing enterprises in China, such as employment, capital stock, gross output, value added, firm identification (e.g., company name, telephone number, zip code, contact person, etc.), and complete information on the three major accounting statements (i.e., balance sheets, profit & loss accounts, and cash flow statements).

Then we match the firm-product-level trade data from the Chinese Customs Database to the NBSC Database, according to the contact information of manufacturing firms, because there is no consistent coding system of firm identity between these two databases.[12] We also exclude all intermediary firms or trading companies as well as processing firms from the customs database. Compared with all the exporting and importing firms under ordinary trade regime reported by the Customs Database, the matching rate of our sample (in terms of the number of firms) covers 45.3% of exporters and 40.2% of importers, corresponding to 52.4% of total export value and 42% of total import value reported by the Customs Database. Compared with the manufacturing exporting firms in the NBSC Database, the matching rate of our sample (in terms of the number of firms) varies from 54% to 63% between 2001 and 2006, which covers more than 60% of total value of firm exports in the manufacturing sector reported by the NBSC Database. We cannot compare our sample with the NBSC Database regarding the number of importers and total import value because the NBSC Database does not contain any information on firms' imports.

[11]As imports under ordinary trade regime include final goods and intermediate goods, we use the Broad Economic Categories (BEC) classification to distinguish final goods and intermediate goods.

[12]In the NBSC Database, firms are identified by their corporate representative codes and contact information. While in the Customs Database, firms are identified by their corporate custom codes and contact information. These two coding systems are neither consistent, nor transferable with each other.

3 Stylized Facts

This section documents four stylized facts about the relationship between trade liberalization and export prices and how this relationship depends on product differentiation as well as firms' import dependence and productivity change using Chinese data. As China joined the WTO in the December of 2001, we use the data from 2001 to represent the pre-liberalization period, and then use the data from 2006 to represent the post-liberalization period. Using the data from the year other than 2006, for example, 2005 or 2004, yields similar results, as long as sufficient time is allowed for firms to adjust their responses to tariff reductions. The four findings are presented as follows.

First, we examine the changes in export prices by the same group of firms that are present in both pre- and post-liberalization periods (see Table 1). To control for the initial productivity, we divide firms into two groups, namely, firms with productivity below and above the 50th percentile, according to their labor productivity (value added per worker) in 2001.[13] For each group we compute the median and mean (log) export price per product per firm in 2001 and in 2006.

Table 1: Export Prices in 2001 and 2006

	Productivity ≤50th (in 2001)		Productivity >50th (in 2001)	
	(1)	(2)	(3)	(4)
	2001	2006	2001	2006
Export Price (HS6)				
Per Firm-product, median	1.28	1.46	1.52	1.63
Per Firm-product, mean	1.41	1.62	1.90	1.99
Export Price (HS6-country)				
Per Firm-product-country, median	1.25	1.41	1.53	1.59
Per Firm-product-country, mean	1.36	1.55	1.90	1.98

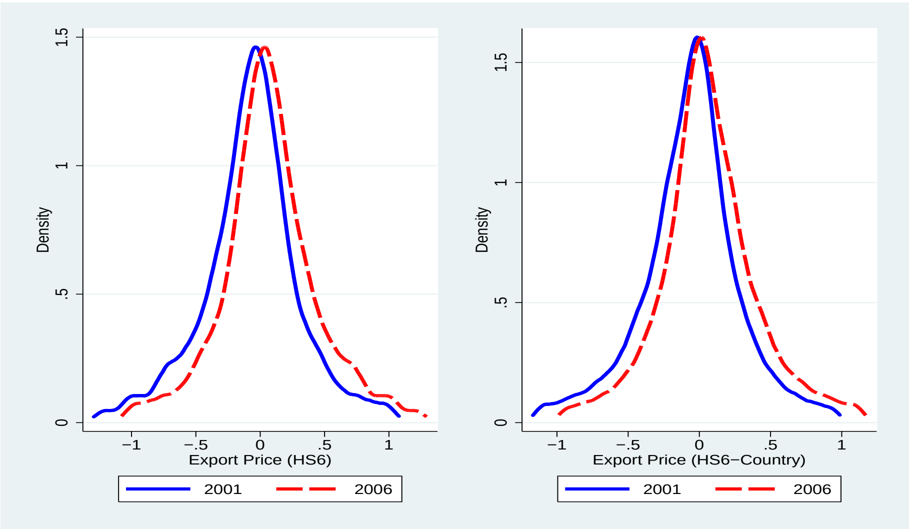

Figure 1: Distribution of Export Prices in 2001 and 2006

[13]Using estimated total factor productivity (TFP) by various methods as group criteria yields similar patterns.

Table 1 shows that on average, from 2001 to 2006 those continuing firms raise unit value export prices, conditional on their initial productivity. To illustrate the shifting pattern between 2006 and 2001, like De Loecker et al. (2012), we plot the distributions of the export price (in natural logarithm). In the left panel of Figure 1, we include only firm-product pairs that are present in both years for the distribution of prices. Then we compare export prices over time by regressing them on firm-product fixed effects and plotting the residuals. Analogously, in the right panel of Figure 1, we include only firm-product-country combinations that are present in both years. Then we compare export prices for each combination over time by regressing them on firm-product-country fixed effects and plotting the residuals. To ensure that our results are not driven by outliers, we remove outliers in the bottom and top 2nd percentiles. The distributions of export prices for both HS6 product and HS6-country move to the right in 2006. Thus, we summarize the first stylized fact as follows:

Stylized fact 1. ***Firms tend to raise export prices in the post-liberalization period.***

Table 2: Change in Export Prices: Differentiated vs. Homogeneous Products

	(1) Whole sample	(2) Differentiated goods	(3) Homogeneous goods
Change in Export Prices (HS6):			
Per Firm-product, median	11.82	14.21	0.44
Per Firm-product, mean	16.36	17.70	7.78
Change in Export Prices (HS6-country):			
Per Firm-product-country, median	10.25	11.35	2.72
Per Firm-product-country, mean	13.47	14.59	4.88

Notes: Change in price is in percentage term.

Second, to explore whether the effect of trade liberalization on prices depends on product differentiation, we divide products into two groups: products with more quality heterogeneity, which we call "heterogeneous-quality products", and products with more quality homogeneity, which we call "homogeneous-quality products". Adopting Rauch's product classification (Rauch, 1999), We use differentiated goods and homogeneous goods as proxies for the above two groups, and compute the change in export prices for these two groups of products. Table 2 shows that the price changes of differentiated goods are significantly larger than those of the whole sample and of homogeneous goods. Figure 2 also presents the differential effect of product differentiation on price distributions: the export prices of differentiated goods significantly increase in 2006 (see Panel (a)); while the export prices of homogeneous goods nearly remain unchanged over time, and in part of the distribution (at HS6 level) even decrease after trade liberalization (see Panel (b)). This suggests that the effect of tariff reduction on export prices depends on product differentiation. The result is summarized as the following finding:

Stylized fact 2. ***In the post-liberalization period, export prices of heterogeneous-quality products significantly increase, while the change in export prices of homogeneous-quality products is nonsignificant and ambiguous.***

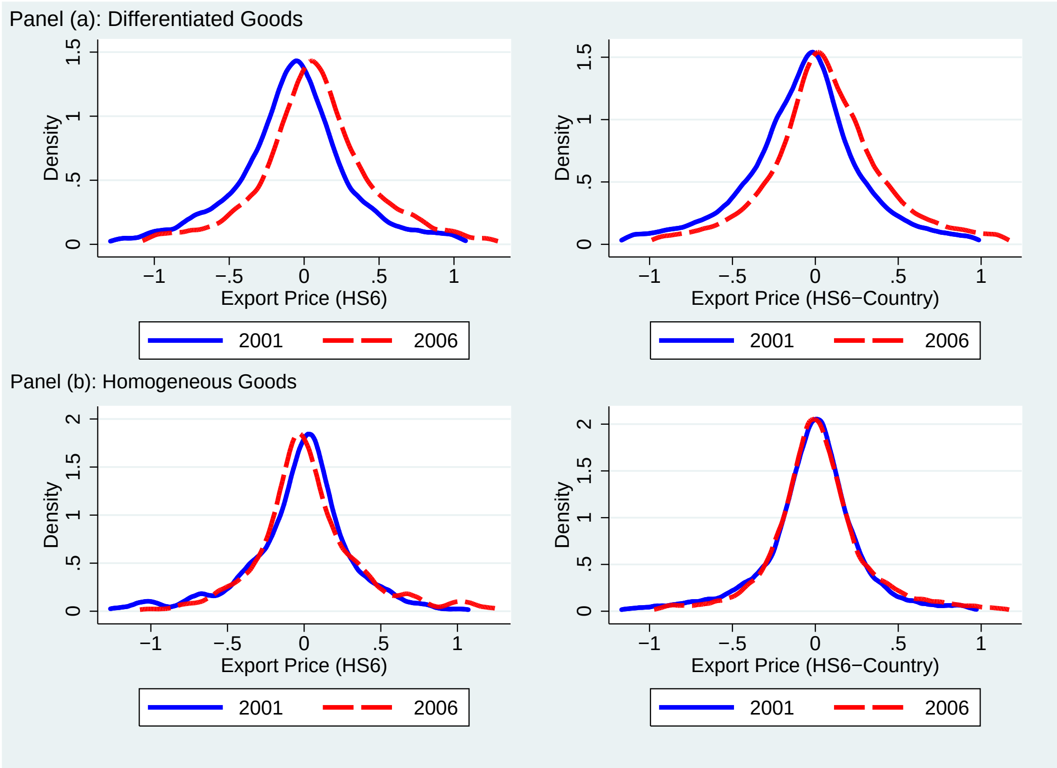

Figure 2: Distribution of Export Prices by Product Differentiation (2001 vs. 2006)

Third, if the impact of trade liberalization on export prices depends on firms' import decisions, we expect to see that the increases in export prices are more profound for firms who become more relying on imports. We compute the average increases in export prices of a HS6 product h by firm f, $\Delta \ln(price_{fh,2006-2001})$, and of a HS6-country combination hc by firm f, $\Delta \ln(price_{fhc,2006-2001})$, for different groups of firms: firms who become more relying on imports vs. firms who do not. To identify the change in firms' dependence on imports, we use four measures: (i) the percentage change of the number of imported varieties; (ii) the percentage change of the number of imported varieties per exported variety; (iii) the percentage change of import value; and (iv) the change in the share of import value in total intermediate inputs value. Using these measures, we divide firms into top and bottom half according to their changes in import dependence, and compare their price changes in Table 3. For each measure, the figures in the the left column are larger than the figures in the right column. In other words, firms with greater increase in their import dependence increase export prices more than firms with smaller increase in import dependence.

We also plot the distributions of export prices in Figure 3. The graphs in Panel (a) plot the distribution of prices for firms whose change in import dependence (under measure (i)) is greater than the 50th percentile; while the graphs in Panel (b) plot for those who have smaller change in import dependence than the 50th percentile. Comparing each graph in Panel (a) with its counterpart in Panel (b), it is clear that the price difference between 2001 and 2006 is more profound in Panel (a) than in

Table 3: Change in Export Prices vs. Change in Import Dependence

Change in import dependence indicated by four measures (i-iv)	(i)		(ii)		(iii)		(iv)	
	(1) >50th	(2) ≤50th	(3) >50th	(4) ≤50th	(5) >50th	(6) ≤50th	(7) >50th	(8) ≤50th
Change in Export Price (HS6):								
Per Firm-product, median	14.32	9.59	12.59	10.96	13.40	10.57	12.96	10.53
Per Firm-product, mean	18.68	14.05	17.54	15.18	17.74	14.99	17.58	15.16
Change in Export Price (HS6-country):								
Per Firm-product-country, median	12.76	7.61	11.77	8.42	11.99	8.64	12.26	7.55
Per Firm-product-country, mean	15.57	11.37	15.05	11.89	14.53	12.41	15.59	11.37

Notes: >50th indicates the firms associated with more substantial increase in import dependence (i.e., the top 50 percentile); ≤50th indicates the firms associated with smaller increase in import dependence (i.e., the bottom 50th percentile). Change in price is in percentage term.

Panel (b). This suggests that export prices rise more significantly for firms who become more import dependent. Thus, we summarize the third finding:

Stylized fact 3. ***In the post-liberalization period, the firms with greater increase in import dependence raise export prices more than those with smaller increase in import dependence.***

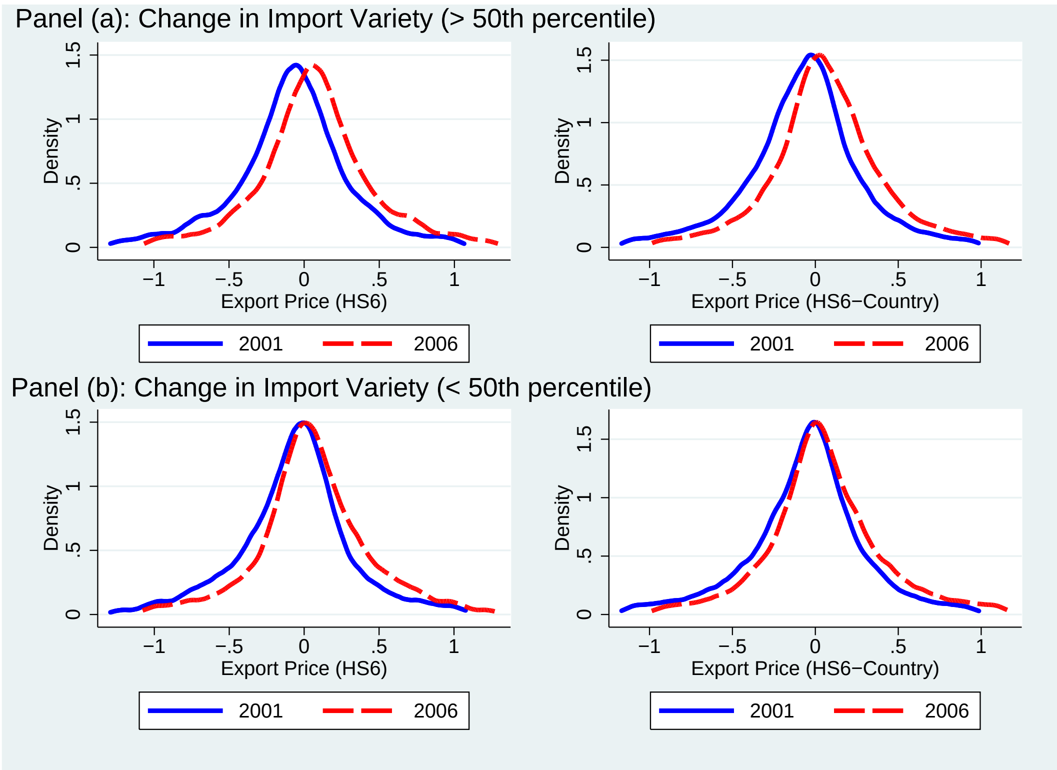

Figure 3: Distribution of Export Prices by Increase in Import Dependence

Fourth, we want to identify how the increase in export prices is related to firm productivity. We report value added per worker as productivity measure in this section. If we use estimated TFP by various methods (such as OLS, O-P, L-P, ACF-OP), the similar patterns remain. We divide firms

Table 4: Change in Export Prices by Productivity Increase

	$\Delta \ln(\text{TFP})_{2006-2001}$	
	(1)	(2)
	>50th	≤50th
Change in Export Price (HS6):		
Per Firm-product, median	15.10	8.63
Per Firm-product, mean	21.28	11.43
Change in Export Price (HS6-country):		
Per Firm-product-country, median	12.97	7.60
Per Firm-product-country, mean	17.70	9.24

Notes: >50th indicates the firms associated with greater increase in productivity (i.e., the top 50 percentile); ≤50th indicates the firms associated with smaller increase in productivity (i.e., the bottom 50th percentile). Change in price is in percentage term.

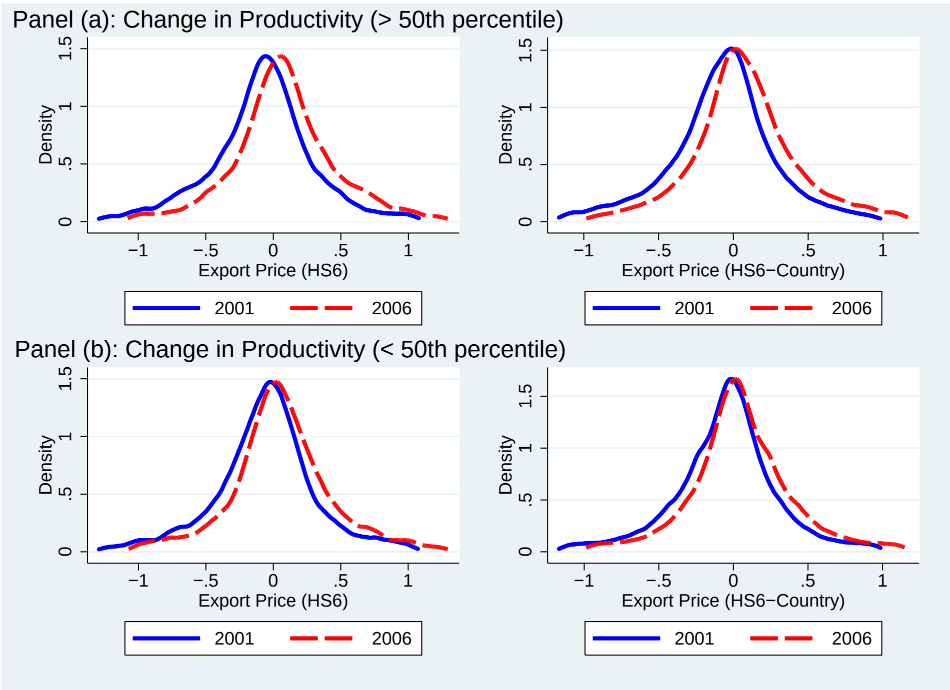

Figure 4: Distributions of Export Prices by Productivity Change

into top and bottom half according to their productivity change. Table 4 shows that firms with greater increase in productivity (column 1) raise export prices more than those with smaller increase in productivity (column 2). In addition, we plot the distributions of export prices for 2001 and 2006 in Figure 4. The graphs in the top panel plot the distributions of export prices for firms whose productivity increase is above the 50th percentile, while the graphs in the bottom panel plot those for firms whose productivity increase is lower than 50th percentile. The contrast between the top and bottom panels confirm the same pattern as in Table 4. Thus, we summarize the last finding:

Stylized fact 4. ***Firms with greater increase in productivity raise export prices more than those with smaller increase in productivity in the post-liberalization period.***

To explain the above stylized facts using a unified framework, we develop a model featuring both cases of heterogeneous quality and homogeneous quality in the next section. We then test the predictions from the model using Chinese data and corroborate the quality upgrading and the increase in unit value export prices after trade liberalization.

4 A Model of Export Price and Quality

In this section we build a partial equilibrium model of trade with heterogeneous firms where each firm uses both domestic and imported intermediate inputs for production to study how import tariff reduction impacts existing two-way traders' unit value export prices via their choice of quality and imported inputs. We extend Melitz's (2003) model of the monopolistic competition framework by introducing endogenous quality. Now, firms choose not only the optimal price but also the optimal quality of products.

4.1 Preference and the Market Structure

For simplification, we assume two symmetric countries, like in Kugler and Verhoogen (2012).[14] In each country, a representative consumer has a constant-elasticity-of-substitution (CES) utility function when she consumes a variety ω:

$$U = \left[\int (q(\omega)x(\omega))^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

where $q(\omega)$ represents quality of variety ω, $x(\omega)$ is the quantity demanded of variety ω, and $\sigma > 1$ is the elasticity of substitution between varieties.[15] Then, consumer optimization yields the following demand for a particular variety, ω, in each country:

$$x(\omega) = (q(\omega))^{\sigma-1} \frac{(p(\omega))^{-\sigma}}{P^{1-\sigma}} S \tag{1}$$

where $P = \left[\int (p(\omega)/q(\omega))^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}$ is an aggregate price index (adjusted by quality), $p(\omega)$ is the (net quality) price of variety ω, and S represents the total spending of each country. Given the same price, higher-quality products attract a larger demand. To simplify notation, the indices for varieties is suppressed hereafter.

[14] Incorporating the asymmetry between home and foreign would not affect our following propositions about the firm's decisions on export prices and quality choices.

[15] $q(\omega)x(\omega)$ captures the quantity of each variety consumed, which is implicitly measured in units of utility.

4.2 Production Technology

Production.—The supply side is characterized by monopolistic competition. Each variety is produced by a single firm, and we focus on existing firms in the industry. Firms are heterogeneous in their initial productivity. This idiosyncratic component of initial productivity is indexed by ϕ. Those existing firms pay a fixed entry cost consisting of f_e units of labor when entering the industry, and then draw their initial productivity ϕ from a common distribution. Each domestic manufacturing firm produces output with productivity ϕ using the following production function:

$$Y = \phi \left(K^a L^{1-a}\right)^{1-\mu} X^{\mu}, \tag{2}$$

where X denotes the intermediate inputs bundle, K and L denote capital and labor employed in production. The intermediate inputs bundle X is assembled from a combination of a bundle of diverse intermediate inputs produced domestically, Z, and another bundle of imported intermediate inputs, M, according to the CES aggregator:

$$X = \left(Z^{\frac{\varsigma-1}{\varsigma}} + M^{\frac{\varsigma-1}{\varsigma}}\right)^{\frac{\varsigma}{\varsigma-1}} \tag{3}$$

where the input bundles themselves are CES aggregates:

$$Z = \left(\sum_l z_l^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} \tag{4}$$

$$M = \left(\sum_{h\in\Omega} m_h^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}} \tag{5}$$

z_l represents the firm's use of domestically produced inputs l, Ω is the set of foreign input varieties imported by the firm and m_h is the quantity of imported input h. The elasticity of substitution $\theta > 1$ is the same within domestic varieties and within foreign varieties, while ς is the elasticity of substitution between the bundles of imported and domestically produced inputs.

Import Decision.—Conditional on being an importer, the import decision a firm needs to make is how many varieties to import. There is a per period fixed cost of importing for each variety imported. Same as in Gopinath and Neiman (forthcoming), we assume that the fixed import cost is increasing in the measure of imported varieties, $|\Omega|$, which can be written as $f_m |\Omega|^{\lambda}$, where $f_m > 0$ and $\lambda > 1$. The presence of these fixed import costs is consistent with the empirical evidence in Bernard et al. (2009) and Halpern et al. (2011).

Each firm chooses capital K, labor L, and the set of domestic inputs $\{z_l\}$, given the wage w, the rental rate of capital r, and the set of domestic intermediate input prices $\{p_l\}$. The firms that import additionally choose the set of imported varieties Ω and the amount of each variety m_h, given the price p_h and import tariff τ_h for each imported product h. To simplify, we assume that wages are the numeraire. The common price index of the (net quality) inputs, c, satisfies:

$$c = \frac{1}{\phi} \frac{P_V^{1-\mu} P_X^{\mu}}{\mu^{\mu} (1-\mu)^{1-\mu}} \tag{6}$$

where $P_V = a^a (1-a)^{1-a} r^a$ is a constant that does not vary across firms, and $P_X = \left(P_Z^{1-\varsigma} + P_M^{1-\varsigma}\right)^{\frac{1}{1-\varsigma}}$. The domestic input price index:

$$P_Z = \left(\sum_l p_l^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{7}$$

is the same for all firms, while the imported input price index:

$$P_M = \left(\sum_{h \in \Omega} (\tau_h p_h)^{1-\theta}\right)^{\frac{1}{1-\theta}} \tag{8}$$

differs across firms because they import a different measure of varieties, $|\Omega|$, and face different import tariff, τ_h, for each particular imported input h. Hence, there exist two channels to reduce the unit cost via firms' import decisions: (i) when firms import an input h with lower tariff τ_h, they tend to have a lower imported input price index; (ii), The larger the measure of imported varieties $|\Omega|$, the lower the intermediate input cost index, all else equal. The lower unit cost could be viewed as equivalent to the improvement of production efficiency. Therefore, the import tariff and the number of imported varieties could effectively affect its production efficiency.

Marginal Cost and Other Fixed Costs.—Following the recent quality-and-trade literature, we assume that there is a positive relationship between quality and marginal cost of production. The rationale is that a higher marginal cost is required to produce a higher-quality product. The positive relationship between quality and marginal cost is common to the recent quality-and-trade literature, including Baldwin and Harrigan (2011), Johnson (2012), and Verhoogen (2008). In this paper, the marginal cost of production is assumed to be cq^{α}, where $\alpha \in (0,1)$ and c denotes the common price index of the inputs (e.g., labor, capital, intermediate inputs). Hence, the marginal cost increases in quality q, and α captures the elasticity of marginal cost with respect to quality. In addition, there exists fixed costs of production, which is assumed to be equal to $f_d q^{\beta}$ ($\beta > 0$). It represents the fixed investments in production associated with quality improvement (e.g., R&D expenditures to improve the product quality or costs of employing higher-quality inputs), where f_d is a constant and $1/\beta$ measures the effectiveness of fixed investment in raising quality. As is standard in a Melitz-type model, firms also face the fixed exporting cost f_x. We assume that all these fixed costs are due every period. The timing of the events for a firm could be summarized as follows: at the beginning of each period, an existing exporter draws productivity ϕ; given productivity and imported inputs (which could be modeled as endogenous decisions by the firm), the firm chooses optimal product quality and set optimal export prices. We focus on the effect of tariff reductions on firm's quality choice and optimal price in the main text, while leave the discussion of the endogenous firm decisions on imported varieties and whether to upgrade technology to Appendix A.2.

4.3 Firm Behavior

To characterize firm behavior, we solve the firm optimization problem with backward induction in the full model. First, we compute its quality choice and the optimal pricing rule given the set of imported inputs and firm productivity. Second, we examine how a reduction in import tariff affects the firm's decision on the set of imported inputs and whether to upgrade technology (see the detailed derivation in Appendix A.2). Third, we revisit the effect of tariff reduction on export prices and product quality with firm's endogenous decisions on imported inputs and technology upgrading.

4.3.1 Export Prices and Quality (Given Import Decision and Productivity)

Given the imported inputs set Ω and productivity ϕ, a firm's profit optimization problem becomes:

$$\max_{p,q} \; (p - cq^{\alpha}) \, q^{\sigma-1} \frac{p^{-\sigma}}{P^{1-\sigma}} S - f_m \left|\Omega\right|^{\lambda} - f_d q^{\beta} + Z \left[(p - cq^{\alpha}) \, q^{\sigma-1} \frac{p^{-\sigma}}{P^{1-\sigma}} S - f_x \right] \tag{9}$$

where Z is an indicator function equalling one if the firm enters the export market, and zero otherwise.[16] Solving this optimization problem with respect to price p and quality choice q yields

$$p = \frac{\sigma}{\sigma - 1} c q^{\alpha} \tag{10}$$

$$q^{\sigma-1} \frac{p^{1-\sigma}}{P^{1-\sigma}} (1 + Z) S = \Lambda q^{\beta} \tag{11}$$

where $\Lambda \equiv \frac{\sigma \beta f_d}{(\sigma-1)(1-\alpha)}$. The above equations imply that the optimal quality chosen by the firm satisfies the following equation:

$$q^{\beta-(\sigma-1)(1-\alpha)} = \frac{(1+Z)S}{\Lambda} \left(\frac{\sigma}{\sigma - 1} \frac{c}{P} \right)^{1-\sigma} \tag{12}$$

Under the condition (i), given by $\beta > (1 - \alpha)(\sigma - 1)$, there is a negative correlation between the common price index of the inputs, c, and the quality choice, q. This condition (i) ensures the existence of the optimal quality. Otherwise, if β is too small, it implies that the firm could easily improve quality without incurring large fixed cost (recall that $f_d q^{\beta}$ represents the fixed production cost), and then the firm would choose quality q to be infinite. According to the input price index equation (6), we know that firms facing a lower import tariff or importing more varieties have a lower input cost c, and hence choose higher quality q.

Combining equations (10) and (12) , the optimal price in this case is given by

$$p = \Lambda^{-\Psi} \left(\frac{\sigma}{\sigma - 1} c \right)^{1+(1-\sigma)\Psi} \left[\frac{(1+Z)S}{P^{1-\sigma}} \right]^{\Psi} \tag{13}$$

[16] If we model exporters alone, it would simplify the current derivation for exporters, but lose the convenience of deriving endogenous decisions on imported inputs and technology upgrading (see Appendix A.2). Hence, to be self-contained, we model both domestic and foreign market from the beginning of our model. We also ignore the variable trade cost, but adding the variable trade cost does not change the subsequent propositions and derivations.

where $\Psi \equiv \frac{\alpha}{\beta-(\sigma-1)(1-\alpha)} > 0$. If the condition (ii), given by $\beta < \sigma - 1$, also holds, then a firm's optimal price is negatively correlated with the input cost c as conditions (i) and (ii) together imply that $1 + (1-\sigma)\Psi < 0$. The condition (ii) ensures that β is not too large. If β is too large, it would be difficult for the firm to adjust quality and to choose higher-quality product as the elasticity of fixed cost of production with respect to quality is high: a small improvement in quality would incur a large increase in fixed production cost.[17] Therefore, a very large β is equivalent to the case that the firm cannot flexibly choose quality, which we call the **homogeneous-quality** case. In other words, in our paper an increase in β leads to less quality differentiation. Conversely, a reasonably small β, which satisfies condition (i) and (ii), is called the **heterogeneous-quality** case. In other words, a decrease in β leads to greater quality differentiation, assuming conditions (i) and (ii) hold. When quality is heterogeneous, more productive firms set higher optimal prices because they use higher-quality inputs, and this proposition is consistent with the recent quality-and-trade literature.[18]

The equations (12) and (13) imply that firms facing a lower import tariff and importing more varieties will choose higher product quality and set higher export prices. Hence, log-linearizing equations (12) and (13) and then taking difference on both sides of equations yields:

$$\Delta \ln q = \beta_{q,\tau}\Delta \ln \tau + \beta_{q,N}\Delta \ln (|\Omega|) + \beta_{q,\phi}\Delta \ln \phi \tag{14}$$

$$\Delta \ln p = \beta_{p,\tau}\Delta \ln \tau + \beta_{p,N}\Delta \ln (|\Omega|) + \beta_{p,\phi}\Delta \ln \phi \tag{15}$$

where

$$\Delta \ln \tau = \sum_{h\in\Omega} \frac{(\tau_h p_h)^{1-\theta}}{\sum_{h'\in\Omega} (\tau_{h'} p_{h'})^{1-\theta}} \Delta \ln \tau_h. \tag{16}$$

$\Delta \ln \tau$ defined by equation (16) reflects the import value weighted average ad valorem tariff change faced by each firm, i.e., a firm-specific tariff change, and $\frac{(\tau_h p_h)^{1-\theta}}{\sum_{h'\in\Omega}(\tau_{h'}p_{h'})^{1-\theta}}$ represents the share of import value of product h in total import value of the firm. We solve that in equations (14) and (15) $\beta_{q,\tau} = \mu \left(\frac{P_M^{1-\varsigma}}{P_Z^{1-\varsigma}+P_M^{1-\varsigma}} \right) (1-\sigma)\Psi/\alpha$ and $\beta_{p,\tau} = \mu \left(\frac{P_M^{1-\varsigma}}{P_Z^{1-\varsigma}+P_M^{1-\varsigma}} \right) (1 + (1-\sigma)\Psi)$. Conditions (i) and (ii) ensure that $\beta_{q,\tau} < 0$, $\beta_{q,N} > 0$, $\beta_{q,\phi} > 0$, $\beta_{p,\tau} < 0$, $\beta_{p,N} > 0$, and $\beta_{p,\phi} > 0$. Given the change in the import set and productivity, the negative values of $\beta_{q,\tau}$ and $\beta_{p,\tau}$ imply that a reduction in import tariff induces firms to raise quality and export prices. In particular, according to equation (10), the effect of tariff on export prices goes through two opposing forces: on one hand, import tariff reduction decreases the (net quality) unit cost of inputs, c, and in turn would reduce optimal export prices—we call this effect the "marginal cost effect"; on the other hand, a lower import tariff induces firms to choose higher quality, and in turn would increase export prices—we call this effect the "quality

[17] $1/\beta$ in our paper is corresponding to the quality differentiation parameter α in Kugler and Verhoogen (2012), which reflects the extent to which quality increases with an increase in fixed quality investment. Following Sutton (1998, 2007), one could think that a higher α is equivalent to the case that the effectiveness of R&D spending in improving the technical dimensions of quality or the effectiveness of advertising expenditures in raising the perceived quality of the firm's output is higher.

[18] See Verhoogen (2008), Kugler and Verhoogen (2012), Hallak (2010), Hallak and Sivadasan (2011), Gervais (2009), Johnson (2012), Manova and Zhang (2012), Fan, Lai, and Li (2012), among others.

adjustment effect". $\beta_{p,\tau} < 0$ implies that the quality adjustment effect dominates the marginal cost effect. Hence, we have the following proposition:

Proposition 1. ***When quality is heterogeneous, a reduction in import tariff induces firms to choose higher quality and to set higher export prices, given the change in the imported varieties and productivity.***

In our paper, $1/\beta$ reflects the quality differentiation. A high β decreases the flexibility of quality choice. When condition (ii) does not hold, a very large β leads to a homogeneous-quality case, in which the flexibility of quality choice is reduced, compared with the heterogeneous-quality case, i.e., a reduction in import tariff would cause a smaller increase in product quality (see equation (12)) when quality is homogeneous. As a result the marginal cost effect would dominate the quality adjustment effect. Therefore, in the homogeneous-quality case we have $\beta_{p,\tau} > 0$, yielding the following proposition:

Proposition 2. ***When quality is homogeneous, a reduction in import tariff induces firms to set lower export prices instead of higher export prices, given the change in the imported varieties and productivity.***

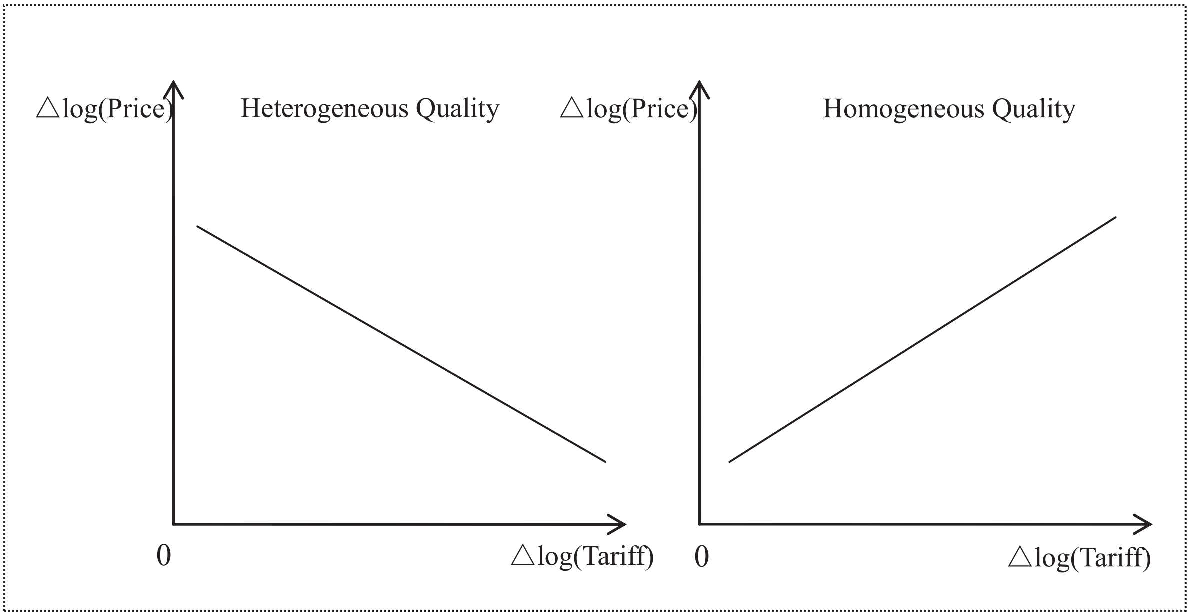

Figure 5: Tariff Reduction and Export Prices (Heterogeneous vs. Homogeneous Quality)

We summarize the impacts of a reduction in import tariff on export prices in Figure 5. The graph in the left panel of Figure 5 illustrates the heterogeneous-quality case in which a reduction in import tariff negatively affects export prices. In other words, import tariff reduction increases export prices when quality is heterogeneous, i.e., when firms have flexibility to adjust product quality. In contrast, the graph in the right panel of Figure 5 illustrates the homogeneous-quality case in which import tariff reduction positively affects export prices and induces firms to set lower export prices after trade liberalization.

4.3.2 Export Prices and Quality Revisited (with Endogenous Imports and Technology Upgrading)

Until now, we assume the given imported product set Ω and productivity ϕ. However, it is reasonable to consider the imported input set and technology as functions of import tariffs, i.e., the tariff reductions could also affect firms' decisions on imports and whether to upgrade technology. We thus derive how import tariff reductions affect a firm's decisions on its imports and whether to upgrade technology (see Appendix A.2). In the literature there has been strong empirical evidence to support the positive effect of trade liberalization on productivity growth (see Amiti and Konings, 2007; Bustos, 2011, among others). Nevertheless, we focus on the effect of trade liberalization on quality choice and export prices. Therefore, in this subsection we revisit how import tariff reduction affects export prices and quality by incorporating the endogenous decisions on imported varieties and technology upgrading.

Effect of Import Dependence.—From equations (14) and (15), we know that $\beta_{q,N} > 0$ and $\beta_{p,N} > 0$ when quality is heterogeneous. Therefore, given the change in technology ($\Delta \ln \phi$), if a firm becomes more dependent on imports, it implies a positive, higher $\Delta \ln (|\Omega|)$ and leads to higher quality and higher export prices with the same extent of tariff reduction. Hence, we have the following proposition:

Proposition 3. ***When quality is heterogeneous, the effect of a reduction in import tariff on optimal quality and export prices is more significant for firms exhibiting greater increase in import dependence.***

Effect of Technology Upgrading.—From equations (14) and (15), we know that $\beta_{q,\phi} > 0$ and $\beta_{p,\phi} > 0$ when quality is heterogeneous. Therefore, given the change in imported varieties ($\Delta \ln (|\Omega|)$), if a firm adopts technology upgrading, it implies a positive, higher $\Delta \ln \phi$ and leads to higher quality and higher export prices with the same extent of tariff reduction. Hence, we have the following proposition:

Proposition 4. ***When quality is heterogeneous, the effect of a reduction in import tariff on optimal quality and export prices is more significant for firms exhibiting greater technology upgrading.***

We summarize the impacts of a reduction in import tariff on export prices when taking into account endogenous firm decisions on imported varieties and technology upgrading in Figure 6. The solid line corresponds to the scenario without change in a firm's endogenous decisions, and the dashed line captures the scenario with change in a firm's endogenous decisions. When quality is heterogeneous, a reduction in import tariff induces firms to set higher export prices (see Proposition 1) and a firm's endogenous decisions will change the slope of the solid line based on Propositions 3-4. This suggests that firms' decisions on import and technology upgrading amplify the effect of trade liberalization

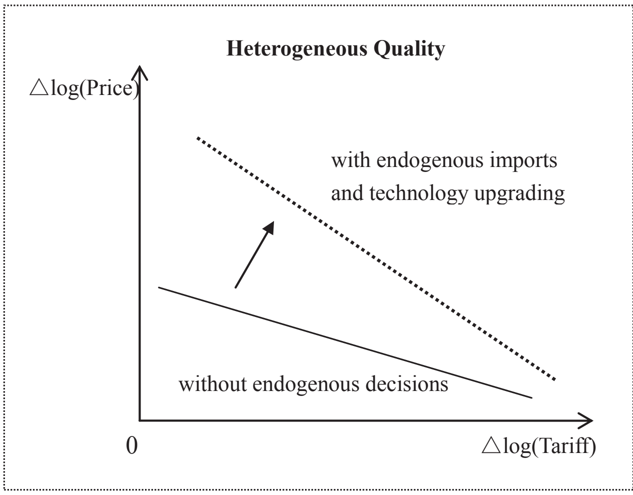

Figure 6: Tariff Reduction and Export Prices (with vs. without endogenous firm decisions)

on quality and export prices. In other words, taking into account a firm's endogenous decisions on imports and technology upgrading, the effect of the same extent of import tariff reduction on export price increase and quality upgrading is greater.

5 Empirical Specifications and Measurement

The above propositions imply that tariff reduction increases export prices through the quality adjustment mechanism when quality is heterogeneous, while the opposite prediction holds when quality is homogeneous. Taking into account endogenous firm decisions on imported varieties and technology upgrading leads to greater effect of tariff reduction on export prices and quality. We present the baseline specifications of the relationship between tariff reductions and export prices in this section, and leave more detailed discussion of estimation specifications together with results on quality in the next section. We also describe the measures of tariff reductions and firm productivity in this section.

5.1 Baseline Specifications

We first employ the following equation to capture the relationship between import tariff and export prices:

$$\ln(p_{fh(c)t}) = \beta_\tau Duty_{ft} + \boldsymbol{\beta}_f \boldsymbol{\chi}_{ft} + \beta_i HHI_{it} + \varphi_{fh(c)} + \varphi_t + \epsilon_{fh(c)t}, \quad (17)$$

where p_{fhct} denotes the unit value export price of HS6 product h exported by firm f to destination country c in year t; $Duty_{ft}$ is import tariff faced by firm f in year t. The specification can represent a firm-product-destination-level (fhc) regression or one at the firm-product level (fh), in which case the optional c subscript is omitted.[19] The vector $\boldsymbol{\chi}_{ft}$ consists of the observables at firm level that potentially impact export prices to control for productivity, imported varieties, and scale effect. Those firm-level controls include firm productivity (estimated TFP), capital intensity (capital to labor ratio), firm size (measured by total employment), total wage bill, and the number of imported varieties. In this paper, we focus on the quality effect. Hence, we add HHI_{it} to control for the competition effect which denotes Herfindahl index, computed at the 4-digit CIC (Chinese Industrial Classification) industry level. Finally, the error term is divided into fixed effects terms and the idiosyncratic term: (1) firm-product(-destination) fixed effects, $\varphi_{f(h)c}$, are included to control for unobserved firm-product(-destination)-level heterogeneity; (2) year fixed effects, φ_t, are included to control for shocks over time that affect export prices across all firm-product(-destination) combinations; (3) an idiosyncratic effect $\epsilon_{fh(c)t}$ with normal distribution $\epsilon_{fh(c)t} \sim N(0, \zeta^2_{fh(c)})$ to control for any other unspecified factors.

To explore the effect of tariff reductions on the change in export prices, we focus on the long-difference estimation of equations (17), using

$$\Delta \ln(p_{fh(c)t}) = \beta_\tau \Delta Duty_{ft} + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_{ft} + \beta_i HHI_{i(t-3)} + \varphi_t + \epsilon_{fh(c)t}, \tag{18}$$

where Δ denotes a change in a variable during a three-year periods. In other words, we take a three-year difference to define the change in any variable x, Δx, as its difference between year t and year $t-3$.[20] We use long difference because of the lagged effect of trade liberalization: long difference provides firms with sufficient time to adjust their export prices through importing. When we use first difference estimation, we have nonsignificant results due to insufficient time of adjustment. Therefore, in our main results, we report results of three-year difference estimation. Nevertheless, the results in different period difference would be reported as robustness checks (see Section 7).

Note that time-invariant firm-product(-destination) fixed effects in equation (17) have already been differenced out. As the variable of interest in equation (18) is the change in firm-level tariffs, $\Delta Duty_{ft}$, we also cluster error terms at firm level to address the potential correlation of error terms within each firm across different products over time.[21] Identification in this model, then, is based on changes over time in the export prices within a firm for each product due to changes in tariffs. It is also worth noting that in equation (18) we take the changes in firm-level controls, which are expected to affect the changes in prices. If we use the initial level of firm characteristics, $\boldsymbol{\chi}_{f(t-3)}$, as firm controls, our results remain robust. As for the industry-level competition control, we use the initial level of Herfindahl index, $HHI_{i(t-3)}$, but using ΔHHI_{it} does not alter the expected sign of the coefficient of $\Delta Duty$.

In addition, we adopt an variant of equation (18), with dependent variable Δp_{ft} representing the

[19] In the paper, we only define the firm-specific tariff reductions according to our theoretical derivation. Hence, for the estimation of equation (17), we only use industry input tariff and output tariff to test the relationship between tariffs and export prices, and the results are shown in Section 7 as robustness check. In the main results, we only report the results of long-difference estimation using firm-specific tariff reduction measures.

[20] It means that for any variable x, $\Delta x_t \equiv \Delta x_{t-(t-3)} \equiv x_t - x_{t-3}$.

[21] When we use the industry-level tariff measures, we cluster standard errors at the industry level.

price change at the firm level. Δp_{ft} is a firm-level price change index, constructed by using a Tornqvist index, as in Smeets and Warzynski (forthcoming):

$$\Delta p_{ft} = \sum_{h} \bar{s}_{fht} \Delta \ln(p_{fht}) \tag{19}$$

where

$$\Delta \ln(p_{fht}) = \ln(p_{fht}) - \ln(p_{fh(t-3)})$$

and

$$\bar{s}_{fht} = \left(s_{fht} + s_{fh(t-3)}\right)/2$$

where p_{fht} is the average price of product h by firm f in year t and s_{fht} is the share of exported product h in firm f's total export sales at year t. Therefore, Δp_{ft} is computed as a weighted average of the growth in prices for all the individual products within firm f.

5.2 Tariff

As the main interest of this paper is to explore the effect of trade liberalization on export prices and product quality, it is important to properly measure effective tariff reductions faced by firms when they import different bundles of intermediate inputs. Hence, we need to compute a firm-specific import tariff reductions to measure trade liberalization faced by each individual firm. We well acknowledge the endogeneity issue of the firm-specific measure of tariff reductions. We will use instrumental variable estimation to address the endogeneity and also employ changes in industry input tariffs and output tariffs to verify the predictions from our model. Using changes in industry input tariffs and instrumental variable estimation does not alter the main results.

The firm-specific measure of tariff reductions has distinct advantages over the conventional industry-level measure of tariff reductions. While the prior studies usually use the industry-level input tariff reductions as the measure of trade liberalization (Amiti and Konings, 2007; Goldberg et al., 2010; Topalova and Khandelwal, 2011, among others), the industry-level measures of tariff reductions may not reflect actual tariff reductions faced by the importers (Ge et al., 2011). Consider two firms that produce the same HS6 product, but they may import different intermediate inputs, according to their own import decisions on different input varieties. A firm that needs to upgrade its products may need to import some generic inputs such as computers and machinery. The conventional industry-level tariff measures rely on the input-output tables. Thus, using the industrial tariff measures would assign the same tariffs to these two firms since they produce the same product and belong to the same industry, even though their actual bundles of imported inputs are different. During the trade liberalization, if tariff reductions in computers and machinery are different from tariff reductions in other intermediate inputs for that industry, the effective import tariff reductions faced by these two firms would be essentially different. Thus, the conventional industry-level measure of tariff reductions ignore the variations of tariffs within the industry, and possibly underestimate the effective tariff reductions (Ge et al., 2011), while the firm-specific measures of tariff reductions can better reflect the heterogeneity of tariff reductions within the industry. Besides being a direct measure of effective tariff reductions faced by the firm, another advantage of the firm-specific tariff reduction measure is avoiding the potential bias created by the multiple-links procedure in constructing the industry-level tariffs (Ge et al., 2011). In addition, using conventional approach to construct industry-level tariff measures might face a possible pitfall because input-output tables are not updated every year but real tariffs change annually. Therefore using time-invariant input-output tables may not accurately measure the effective trade protection faced by each firm (Yu and Tian, 2013). Next, we present different ways to compute effective import tariff reductions faced by firms as firm-specific measures of trade liberalization.

First and foremost, we follow our theoretical derivation in the model (see equation (16) in Section 4.3.1), $\Delta \ln \tau = \sum_{h \in \Omega} w_h \Delta \ln \tau_h$, where the weight is the import share of product h in the total import value by the firm, $w_h = \frac{(\tau_h p_h)^{1-\theta}}{\sum_{h' \in \Omega} (\tau_{h'} p_{h'})^{1-\theta}}$, to compute a firm-specific measure of tariff reductions, i.e., a firm-specific change in import tariffs, $\Delta \ln \tau \equiv \Delta Duty$. Here, in the computation of the firm-specific tariff reductions, we use an approximation that at product level $\Delta \ln \tau_h \approx \Delta Duty_h$.[22] This firm-specific input tariff reduction measure is theoretically justified, and can reflect the changes in effective tariffs faced by each firm due to its responses to trade liberalization when the firm alters its input bundles over time. Second, we adopt four alternative measures of firm-specific tariff reductions to illustrate the robustness of our results.

We first compute the firm-level tariff change, $\Delta Duty_{ft} \equiv \sum_{h \in \Omega_{ft}} w_{ht} \Delta Duty_{ht}$, where $\Delta Duty_{ht}$ is the change in import duty for the imported product h in year t, Ω_{ft} is the set of imported varieties by firm f in year t, and w_{ht} is the weight, defined as the share of import value of product h in total import value by firm f in year t. Then, in computing $\Delta Duty_{ft}$, we use various methods as follows:

(1) We want to ensure that the effective tariff change is indeed driven by the exogenous changes in tariffs and not driven by the endogenous changes in the weights. Therefore, we compute unweighted firm-specific tariff change, $\Delta Duty_{ft} = \sum_{h \in \Omega_{ft}} \Delta Duty_{ht}$, to avoid the endogenous problem of the weight change across products for each firm.

(2) To further alleviate the endogenous change in the set of imported inputs, we adopt the firm-specific tariff measure by Ge et al. (2011) and fix the set of imported varieties during the whole sample period and compute $\Delta Duty_{ft} = \left(\sum_{h \in \Omega} \Delta Duty_{ht}\right) / |\Omega|$, where Ω is the total set of imported varieties during the sample period, and $|\Omega|$ denotes the total number of imported varieties by firm f over the whole sample period. By fixing the total number of imported varieties over the sample period, this measure focuses on the pure changes in tariff reduction rather than the changes in input bundles.

[22]Note that the import tariff τ in our model has its empirical counterparts, $1 + Duty$, since the import price in Chinese customs data is fob price. Then we use the approximation that $\Delta \ln \tau_h = \Delta \ln(1 + Duty_h) \approx \Delta Duty_h$, according to $\ln(1 + x) \approx x$.

(3) To consider only imported intermediate inputs, we drop all imported final goods and compute the weighted firm-specific import tariff change in intermediate goods. The final goods and intermediate goods are defined by the Broad Economic Categories (BEC) classification. Note this measure of tariff reduction generates smaller sample size as it loses those firms that only import final goods as inputs to produce exported products.[23]

(4) We follow Manova and Zhang (2012b) to focus on foreign inputs in the same broad industry classification as the output product. For example, if a firm buys brakes and safety seat belts and sells cars, both its exports and imports would be recorded in the motor vehicles industry. The average ad valorem duty reduction in its imported inputs such as brakes and safety seat belts would be a proxy for the import tariff change faced by the firm that produces cars. If the company also manufactures cell phones, tariff reduction in SIM cards would enter the measure of import tariff change of its cell phones but not that of its cars. Therefore, for each exported product by a particular firm, we construct the weighted average tariff change across all the inputs imported by the firm (e.g. brakes, safety seat belts) in a given HS2 category (e.g. motor vehicle). We then assign this average tariff change to all products exported by this firm in the same HS2 category (e.g. cars and potentially trucks). Therefore, using this method we eventually compute firm-product specific tariff change $\Delta Duty_{fht}$ for each product h exported by firm f in year t.[24] Among all the four alternative firm-specific tariff reduction measures, this one generates the smallest sample size.

Last but not least, we acknowledge that firm-specific measures of import tariff reductions have pros and cons. On one hand, they can more precisely reflect the real effective import tariff reductions faced by firm and thus the extent to which trade liberalization affects each individual firm. On another hand, firm-specific tariff reduction is more likely to be affected by endogeneity problem since a firm will change its import decision when facing trade liberalization. Hence, we also compute changes in industry input and output tariffs using input-output tables to test our theory and confirm the robustness of our results.

Therefore, we present the results based on the first measure of firm-specific tariff reduction, i.e., the import value weighted average tariff reduction, but we also report the results based on alternative measures of tariff reductions (including the industry-level tariff reduction measure) and the instrumental variable estimation. All various measures of tariff reductions yield similar empirical results and thus support the propositions of our model.

[23]Using this measure loses approximately 10% observations in our sample.

[24]We also compute this tariff measure at HS4 level by assigning the average tariff across all the imported inputs in a given HS4 category to all products exported by the same firm within the same HS4 category and it yields the similar results. Those alternative results are available upon request.

5.3 Productivity

To capture firms' productivity, we estimate both total factor productivity (TFP) and labor productivity (measured by value added per worker). For TFP, we adopt various methods to estimate, including the augmented Olley-Pakes (hereafter OP) method (Olley and Pakes, 1996), the OLS method, the Levinsohn-Petrin (hereafter LP) method (Levinsohn and Petrin, 2003), and the Ackerberg-Caves-Frazer (hereafter ACF) augmented O-P method (Ackerberg et al., 2006). Our main results are based on the OP method, but using other methods to estimate productivity does not alter the main results.

Our OP estimation approach builds upon the recent development in augmenting the original OP method, including Amiti and Konings (2007), Feenstra et al. (forthcoming), and Yu (2011), to deal with the simultaneity bias and selection bias. The production function we use is a Cobb-Douglas production function:

$$Y_{ft} = \phi_{ft} \left(K_{ft}^{a} L_{ft}^{1-a} \right)^{1-\mu} X_{ft}^{\mu},$$

where production output of firm f at year t, Y_{ft}, is a function of labor, L_{ft}, and capital, K_{ft}; ϕ_{ft} captures firm f's TFP in year t.

We use deflated firm's value-added to measure production output. We do not include intermediate inputs (materials) as one of input factors in our main results because the prices of imported intermediate inputs are different from those of domestic intermediate inputs.

To measure real terms of firm's inputs (labor and capital) and value added, we use different input price deflators and output price deflators from Brandt et al. (2012).[25] The output deflators are constructed using "reference price" information from China's Statistical Yearbooks, and the input deflators are constructed based on output deflators and China's national input-output table (2002). Then we construct the real investment variable by adopting the perpetual inventory method to investigate the law of motion for real capital and real investment. To capture the depreciation rate, we use each firm's real depreciation rate provided by the NBSC firm-production database.

To take into account firm's trade status in the TFP realization, similar as in Amiti and Konings (2007), we include two trade-status dummy variables-an export dummy (equal to one for exports and zero otherwise) and an import dummy (equal to one for imports and zero otherwise). Furthermore, to capture the pre- and post-period of China's accession to WTO, we include a WTO dummy (i.e., one for a year since 2002 and zero for before) in the Olley-Pakes estimation as the accession to WTO represents a positive demand shock for China's exports.

[25] The data can be accessed via http://www.econ.kuleuven.be/public/N07057/CHINA/appendix/.

6 Results

We first test the effect of import tariff reduction on export prices and product quality given productivity and imported varieties, and confirm the differential effect under the heterogeneous and homogeneous quality (Propositions 1 and 2). Then we revisit the effect of tariff reduction on export prices and quality when taking into account the changes in firm endogenous decisions on imports and technology upgrading to verify Propositions 3 and 4. Note that we also test the effect of tariff reduction on imported varieties and technology upgrading in Appendix.

Recall that we do not include the firms in the "processing trade" regime in our estimation since the government usually offers import tariff exemption in order to encourage processing trade. Although processing firms may be affected by import tariff reduction through competition effect, the quality mechanism is more profound for firms conducting ordinary trade: import tariff reduction, net the competition effect, implies that the imported inputs become cheaper for ordinary traders, and hence encourages ordinary traders to choose more higher-quality imported varieties as inputs. Therefore, in this section we report main results based on the sample of ordinary trading firms, which suits the purpose of investigating the channel of quality adjustment. However, we also use processing exporters as control group to show that processing firms do not significantly increase export prices and quality, and report the corresponding results in the next section as robustness checks.

6.1 Effects of Trade Liberalization on Export Prices and Quality

Our results significantly support Proposition 1, indicating that import tariff reduction indeed induces Chinese firms to increase export prices and quality in general, which is consistent with the predictions from the heterogeneous-quality case. However, we also find evidence to support the predictions for the homogeneous-quality case (Proposition 2) by estimating quality-adjusted price and comparing goods with different quality differentiation. Admittedly, tariff reductions are potentially endogenous. We will address this issue later using alternative tariff measures and instrumental variable estimation in the end of this subsection.

6.1.1 Baseline Regressions

Table 5 reports the long-difference estimation results of equation (18), which is our key specification. We use three dependent variables, namely, the change in export prices (i) for a firm-product-destination combination, (ii) for a firm-product combination, and (iii) for a firm. Note that tariff reductions are exogenous from the perspective of the firm and the time-invariant firm fixed effects have been differenced out.

Specifications 1-4 report results with the price change at firm-product-destination level as dependent variable. In column 1, we regress the change in log export price on tariff reductions solely, without adding any control variables, while in column 2 we add firm-level controls and the Herfindahl index (HHI) at industry level. In both columns 1 and 2, the coefficients on tariff change ($\Delta Duty$) are negative and significant at, at least, 10 percent level. Then in columns 3-4, we compute the cluster-robust standard error estimator for columns 1 and 2 by clustering error terms at firm level to control for any potential correlation within each firm. Now the coefficients on $\Delta Duty$ become less significant, but still negative and significant at, or below, 10.1 percent level in column 3 and 13.7 percent level in column 4, respectively.

Specifications 5 and 6 report the results with the price change at firm-product level as dependent variable, and specifications 7 and 8 report the results based on the firm-level price change as dependent variable. In columns 5-8, all standard errors are robust, corrected for clustering at firm level. Again, all coefficients on tariff reductions are negative and significant at, at least, 10 percent level, confirming that tariff reductions increase export prices at various aggregation levels. This provides evidence to support the prediction of the heterogenous-quality model as in Proposition 1 that a reduction in import tariff leads to higher export prices.

Table 5: Basic Results (Long-difference Estimation)

	Dependent Variable							
	$\Delta\ln(\text{Export Price}_{fhct})$				$\Delta\ln(\text{Export Price}_{fht})$		$\Delta\text{Export Price Index}_{ft}$	
Regressor:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔDuty	-0.195**	-0.175*	-0.195	-0.175	-0.402**	-0.362**	-0.313*	-0.301*
	(0.095)	(0.095)	(0.119)	(0.118)	(0.173)	(0.172)	(0.161)	(0.159)
Δln(TFP)		0.010***		0.010		0.014**		0.017**
		(0.003)		(0.006)		(0.007)		(0.008)
Δln(Capital/Labor)		0.003		0.003		0.0003		0.005
		(0.005)		(0.008)		(0.010)		(0.012)
Δln(Labor)		0.011*		0.011		0.015		-0.006
		(0.006)		(0.012)		(0.015)		(0.015)
Δln(Wage)		0.006		0.006		0.014		0.027*
		(0.006)		(0.010)		(0.011)		(0.015)
Δln(Import Varieties)		-0.0004		-0.0004		0.007		0.014*
		(0.003)		(0.006)		(0.006)		(0.007)
HHI		-0.232***		-0.232*		-0.343***		-0.133
		(0.063)		(0.124)		(0.123)		(0.165)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Clustering at firm level			yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	37,175	37,175	10,398	10,398
R-squared	0.0019	0.0022	0.0019	0.0022	0.0016	0.0024	0.0021	0.0041

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses in all columns except for columns 1 and 2. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (t-3) at the 4-digit CIC industry in China.

Note that the results with prices at the HS6-country level are less significant than the ones with prices at the HS6 product level. The reason why the coefficients on tariff, TFP and import variety are less significant for $\Delta\ln(\text{Export Price}_{fhct})$, compared with $\Delta\ln(\text{Export Price}_{fht})$, is that most price changes happen when switching destination countries. In other words, after quality upgrading, within the same HS6 product, a firm tends to export more to developed countries instead of developing countries, and thus the price increase for a given HS6 product is largely driven by the within-product, yet cross-country switching. This is also consistent with the stylized fact we presented in Table 2 where the mean and median changes in export prices of HS6 product are significantly greater than the ones of HS6-country combination for both the whole sample and differentiated goods.

In Table 5, the signs of coefficients on control variables are also consistent with the theory. For example, the coefficients on TFP are positive and significant in all specifications except for column 4. This suggests that more productive firms also choose higher prices, which is consistent with the recent quality-and-trade literature (e.g., Hallak, 2010; Kugler and Verhoogen, 2012; Johnson, 2012, among others). The coefficients on other firm-level controls (capital intensity and wage bill) are also related to productivity and therefore present the same sign as the coefficients on TFP. The coefficients on log import varieties are non-significant in most specifications but significantly positive in the last column. Note that our theory predicts that the change in TFP and the change in the number of imported varieties are functions of import tariff reductions as firms respond to trade liberalization by adjusting their import set and their technology upgrading decision. Therefore, it is not surprising to see non-significant coefficients on TFP and import varieties when we include the change in tariff ($\Delta Duty$) in regression. Nevertheless, we will report the net effect of TFP and import varieties on price and quality in the end of next section after quality estimation.

The last control variable, Herfindahl index (HHI), is used to control for the industry-level competition effect. A lower Herfindahl index denotes tougher competition in the industry. As our HHI is computed at the level in the initial year, a higher-HHI sector indicates higher monopoly profits at the beginning and in turn attracts more firms to enter. Hence, this sector would experience a greater raise in competition. As a result, firms in this sector would charge lower prices. This explains why the coefficients on HHI are negative.[26]

6.1.2 Quality and Quality-Adjusted Prices

The key mechanism of our model is the choice of quality. The results in Table 5 support the predictions from the heterogeneous-quality case that tariff reduction induces firms to raise export prices. However, whether the increase in unit value export prices essentially reflects the quality improvement remains to be answered. In this subsection, we estimate quality of exported products and regress estimated quality on tariff reductions to address the effect of trade liberalization on quality upgrading. Then we sort out the quality effect to obtain quality-adjusted prices to test the prediction of the homogeneous-quality case.

[26] The data also present that the initial level of HHI is significantly, negatively correlated with the change in HHI. When we regress the price changes on ΔHHI, the coefficients are positive.

It is not easy to directly measure quality, but we can infer quality from observed prices and demand. We estimate "quality" of exported product h shipped to destination country c by firm f in year t, q_{fhct}, via the following empirical demand equation based on equation (1), the demand equation, in our model:

$$x_{fhct} = q_{fhct}^{\sigma-1} p_{fhct}^{-\sigma} P_{ct}^{\sigma-1} Y_{ct} \tag{20}$$

where x_{fhct} denotes the demand for a particular firm's export of product h in destination country c. Following Khandelwal et al. (forthcoming), we take logs of the above equation, and then use the residual from the following OLS regression to infer quality:

$$\ln(x_{fhct}) + \sigma \ln(p_{fhct}) = \varphi_h + \varphi_{ct} + \epsilon_{fhct} \tag{21}$$

where the country-year fixed effect φ_{ct} collects both the destination price index P_{ct} and income Y_{ct}; the product fixed effect φ_h captures the difference in prices and quantities across product categories due to the inherent characteristics of products. Then estimated quality is $\ln(\hat{q}_{fhct}) = \hat{\epsilon}_{fhct}/(\sigma - 1)$. Consequently, quality-adjusted prices are the observed log prices less estimated quality, i.e., $\ln(p_{fhct}) - \ln(\hat{q}_{fhct})$, denoted by $\ln(\widetilde{p}_{fhct})$. The intuition behind this approach is that conditional on price, a variety with a higher quantity is assigned higher quality.[27] Given the value of the elasticity of substitution σ, we are able to estimate quality from equation (21).

The literature yields and employs various estimates of σ. For example, Anderson and van Wincoop (2004) survey gravity-based estimates of the Armington substitution elasticity (e.g., Head and Ries, 2001; Romalis, 2007), and conclude that a reasonable range is $\sigma \in [5, 10]$.[28] Arkolakis (2010) choose a value of $\sigma = 6$. In our estimation, we use different values at $\sigma = 5$ and $\sigma = 10$. We well acknowledge that the recent development in the literature suggests a lower and narrower range (Simonovska and Waugh, 2013). Hence, to verify the robustness of our results, we also employ the estimated industry-specific elasticities of substitution (σ_i) by Broda and Weinstein (2006) and find that our results are robust to different values of the elasticity of substitution.[29]

Table 6 reports the estimation results of equation (18) with the change in estimated quality as dependent variable. Different columns correspond to using different values of elasticity of substitution in estimating quality. Note that all coefficients on tariff reductions are significantly negative (except for the less significant coefficients in columns 3 and 4), supporting the prediction on quality upgrading from Proposition 1 that a reduction in import tariff induces firms to choose higher-quality products. Again, all coefficients on control variables are consistent with our expectation and the signs are similar as in baseline regressions in Table 5.

[27] See Khandelwal et al. (forthcoming) for detailed review of this approach.

[28] Waugh (2010) obtain similar estimates based on the sample including both rich and poor countries, though the parameter has different structural interpretations.

[29] Broda and Weinstein (2006) estimate the elasticity of substitution for disaggregated categories and report that the average and median elasticity for Standard International Trade Classification 5-digit goods is 7.5 and 2.8, respectively. We use the concordance between HS 6-digit products and SITC to merge their estimates with our sample.

Table 6: Effect of Tariff Reductions on Quality Upgrading

	Dependent Variable: $\Delta \ln(\hat{q}_{fhct})$							
	$\sigma = 5$		$\sigma = 5$		$\sigma = 10$		$\sigma = \sigma_i$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔDuty	-0.250**	-0.230*	-0.250	-0.230	-0.282**	-0.262*	-0.447***	-0.416***
	(0.122)	(0.122)	(0.162)	(0.160)	(0.135)	(0.134)	(0.152)	(0.148)
Δln(TFP)		0.024***		0.024***		0.016**		0.022***
		(0.004)		(0.008)		(0.007)		(0.007)
Δln(Capital/Labor)		0.023***		0.023*		0.010		0.0163
		(0.006)		(0.012)		(0.010)		(0.011)
Δln(Labor)		0.080***		0.080***		0.038***		0.054***
		(0.008)		(0.015)		(0.013)		(0.015)
Δln(Wage)		0.018**		0.018		0.012		0.005
		(0.007)		(0.011)		(0.010)		(0.011)
Δln(Import Varieties)		0.010**		0.010		0.004		0.007
		(0.004)		(0.007)		(0.006)		(0.007)
HHI		-0.173**		-0.173		-0.212		-0.360**
		(0.081)		(0.191)		(0.139)		(0.169)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Clustering at firm level			yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736	79,736	79,736	79,736
R-squared	0.0005	0.0025	0.0005	0.0025	0.0006	0.0014	0.0011	0.0026

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses in columns 3-8. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (t-3) at the 4-digit CIC industry in China.

Table 7 reports the estimation results of equation (18) with the change in estimated quality-adjusted price, i.e., $\ln(p_{fhct}) - \ln(\hat{q}_{fhct})$, as dependent variable. Similar with Table 6, we report estimation results based on different values of elasticity of substitution. By construction, the quality-adjusted prices have sorted out the quality effect and should follow the homogeneous-quality case. Therefore, according to Proposition 2 that a reduction in import tariff induces firms to set lower export prices when quality is homogeneous, we expect positive coefficients on ΔDuty. The results in Table 7 confirm this proposition. The coefficients on ΔDuty in Table 7 are all significantly positive in columns 5-8. In columns 1-4, the coefficients are also positive though non-significant, probably because the previous method cannot perfectly sort out the embodied quality effect from observed prices. Note that the coefficients on TFP and the number of imported varieties are also significant with the opposite signs as in the heterogeneous-quality case. This indirectly confirms that the heterogeneous-quality and the homogeneous-quality cases are intrinsically different. Hereafter, when we use estimated quality or quality-adjusted price, we only report results based on industry-specific elasticity of substitution from Broda and Weinstein (2006) for the sake of conciseness.[30]

In the previous estimations, we find significant effect of tariff reductions on price change and quality upgrading. However, the coefficients on the change of (log) TFP and the change of the (log) number

[30]Results based on other values of elasticity of substitution remain qualitatively the same and are available upon request.

Table 7: Effect of Tariff Reductions on the Change in Quality-Adjusted Prices

	Dependent Variable: $\Delta\left[\ln(p_{fhct}) - \ln(\hat{q}_{fhct})\right] \equiv \Delta\ln(\widetilde{p}_{fhct})$							
	$\sigma = 5$		$\sigma = 5$		$\sigma = 10$		$\sigma = \sigma_i$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔDuty	0.055	0.054	0.055	0.054	0.087*	0.086*	0.252***	0.241***
	(0.065)	(0.065)	(0.098)	(0.099)	(0.052)	(0.051)	(0.083)	(0.081)
Δln(TFP)		-0.014***		-0.014***		-0.006***		-0.012***
		(0.002)		(0.004)		(0.002)		(0.004)
Δln(Capital/Labor)		-0.020***		-0.020***		-0.007**		-0.013**
		(0.003)		(0.006)		(0.003)		(0.006)
Δln(Labor)		-0.070***		-0.070***		-0.028***		-0.043***
		(0.004)		(0.009)		(0.004)		(0.009)
Δln(Wage)		-0.012***		-0.012*		-0.006*		0.002
		(0.004)		(0.006)		(0.003)		(0.006)
Δln(Import Varieties)		-0.010***		-0.010***		-0.005**		-0.007**
		(0.002)		(0.004)		(0.002)		(0.004)
HHI		-0.059		-0.059		-0.020		0.128
		(0.043)		(0.143)		(0.065)		(0.124)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Clustering at firm level			yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736	79,736	79,736	79,736
R-squared	0.0109	0.0155	0.0109	0.0155	0.0406	0.0439	0.0222	0.0259

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses in columns 3-8. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (t-3) at the 4-digit CIC industry in China.

Table 8: Net Effect of TFP and Import Varieties

	Dependent Variable:									
	$\Delta\ln(p_{fhct})$	$\Delta\ln(\hat{q}_{fhct})$	$\Delta\ln(\widetilde{p}_{fhct})$	$\Delta\ln(p_{fht})$	Δp_{ft}	$\Delta\ln(p_{fhct})$	$\Delta\ln(\hat{q}_{fhct})$	$\Delta\ln(\widetilde{p}_{fhct})$	$\Delta\ln(p_{fht})$	Δp_{ft}
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Δln(TFP)	0.011***	0.022***	-0.011***	0.017***	0.020***					
	(0.003)	(0.004)	(0.002)	(0.005)	(0.007)					
Δln(Import Varieties)						0.001	0.013***	-0.012***	0.009*	0.014**
						(0.003)	(0.004)	(0.002)	(0.005)	(0.007)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	37,175	10,398	79,736	79,736	79,736	37,175	10,398
R-squared	0.0020	0.0013	0.0224	0.0017	0.0027	0.0018	0.0010	0.0226	0.0015	0.0023

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. All regressions include a constant term.

of imported varieties are sometimes non-significant. Table 8 reports the net effect of TFP and import varieties. Columns 1-5 report the net effect of TFP, while columns 6-10 report the net effect of import varieties. Now all coefficients on TFP and import varieties show the expected signs according to our theory (i.e., negative on quality-adjusted prices in columns 3 and 8, and positive on prices and quality in all the rest of the columns), and all effects are significant (except for column 6).

6.1.3 The Role of Quality Differentiation

According to Propositions 1 and 2, the effect of tariff reduction on export prices depends on quality differentiation. Under the heterogeneous quality, firms increase export prices, while under the homogeneous quality case, firms decrease export prices. From Stylized fact 2, we know that in the real data, the price change for homogeneous product is nonsignificant and ambiguous.

To test whether the homogeneous-quality goods differ from the heterogenous-quality goods, we use both direct and indirect approaches. In the direct approach, we divide the whole sample into two subsamples, the goods with heterogeneous quality and the goods with homogeneous quality, respectively. We then test the relationship between tariff reductions and prices changes using the two subsamples separately. In the indirect approach, we check whether the price increase is significantly smaller under the homogeneous quality case than under the heterogeneous quality case using interaction terms. In other words, we expect to see that the effect of tariff reductions on export price increase is more significant as product quality differentiation increases. It is natural to believe that differentiated products present greater quality differentiation than homogeneous products do. Therefore, we employ differentiated goods and homogeneous goods, based on Rauch's (1999) classification, to proxy for heterogeneous- and homogeneous-quality products.

In the indirect approach, we estimate the following equation:

$$\Delta \ln(p_{fhct}) = \beta_\tau \Delta Duty_{ft} + \beta_H \Delta Duty_{ft} \times HOMOGENEOUS_{fhct} + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_{ft} + \beta_i HHI_{i(t-3)} + \varphi_t + \epsilon_{fhct}, \tag{22}$$

where $HOMOGENEOUS$ is a dummy variable which is equal to one for homogeneous goods and zero for differentiated goods. The coefficient on the interaction term, β_H, is of our interest. We expect a positive β_H and a negative β_τ. Replacing dependent variable $\Delta \ln(p_{fhct})$ with $\Delta \ln(p_{fht})$ or $\Delta \ln(\hat{q}_{fhct})$, we could estimate the variants of equation (22).

Table 9 reports the estimation results of both direct and indirect approach. Columns 1-3 report estimation results when we regress the change in (log) price for HS6-country product on tariff reductions; columns 4-6 report regression results with the change in (log) estimated quality for HS6-country product as dependent variable; columns 7-9 report the results with the change in (log) price for HS6 product as dependent variable. In each of the three columns, the first column uses the subsample of differentiated products and therefore presents the negative coefficient on tariff reductions (see columns 1, 4, and 7) according to Proposition 1; the second one uses the subsample of homogeneous goods and thus yields positive but less significant coefficients on tariff (see columns 2 and 8) according to Proposition 2;[31] the third one presents the estimation results of equation (22) or its variants with different

[31] Proposition 2 does not directly predict that the relationship between quality change and tariff reduction. However, it could be derived that under the homogeneous-quality case, quality would also increase when tariff reduces, but the rise in quality would be smaller and less significant than the quality upgrading under the heterogeneous-quality case. Therefore, we expect a nonsignificant coefficient on $\Delta Duty$ when the regressand is the change in quality. The result in column 5 is consistent with this expectation.

dependent variables (see columns 3, 6, and 9). All coefficients on interaction terms are significantly positive at the (at least) 10 percent level. The results are consistent with our expectation and further substantiate Propositions 1 and 2.

Table 9: Effect of Tariff Reductions (Heterogeneous vs. Homogeneous Quality)

	$\Delta \ln(p_{fhct})$			$\Delta \ln(\hat{q}_{fhct})$			$\Delta \ln(p_{fht})$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	-0.191	0.294	-0.271**	-0.461***	0.040	-0.458***	-0.504***	0.731**	-0.526***
	(0.128)	(0.296)	(0.127)	(0.161)	(0.304)	(0.155)	(0.194)	(0.361)	(0.183)
ΔDuty $\times HOMOGENEOUS$			1.075***			0.467*			1.341***
			(0.288)			(0.280)			(0.300)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	70,389	9,347	79,736	70,389	9,347	79,736	32,088	5,087	37,175
R-squared	0.0023	0.0033	0.0025	0.0027	0.0039	0.0026	0.0026	0.0050	0.0028

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level competition control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

6.1.4 Alternative Measures of Tariff

The previous results are based on weighted firm-specific tariff reductions. To show the robustness of our results, we report results of alternative firm-specific tariff reduction measures in Table 10 and results of industry-level tariff measures in Table 11.

Table 10 reports the results based on alternative firm-specific tariff reduction measures (see detailed description in Section 5.2). Specifications 1 and 2 use unweighted firm-specific tariff reductions; specifications 3 and 4 adopt the tariff reduction measure as in Ge et al. (2011) by fixing the total number of imported varieties during the whole sample period; specifications 5 and 6 employ the weighted firm-specific import tariff reductions of only intermediate goods; specifications 7 and 8 use the tariff reduction measure constructed by following Manova and Zhang (2012b). Panel A reports the results with prices of HS6 products and Panel B presents the results with prices of HS6-country products. In most specifications, the coefficients on the change in import tariff are significantly negative, indicating that import tariff reduction leads to higher export prices and confirming Proposition 1. Also, the coefficients on the interaction terms are all significantly positive, except for using the measure by Manova and Zhang (2012b), implying that the effect of import tariff reduction on export price increase is more significant for heterogeneous-quality products and verifying Proposition 2.

Table 11 reports the results based on industry input and output tariffs. Columns 1-4 present the results using the price change for HS6-country product as dependent variable, and columns 5-8 report the results with the price change for HS6 product. When we regress the price change on industry output tariff change (see columns 1 and 5), the coefficients on output tariff are significantly

Table 10: Alternative Firm-Specific Tariff Reduction Measures

	Firm-specific Tariff Reduction Measures							
	Measure 1		Measure 2		Measure 3		Measure 4	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: dependent variable = $\Delta\ln(p_{fht})$								
ΔDuty	-0.477**	-0.574***	-0.783***	-0.804***	-0.388**	-0.523***	-0.487**	-0.570**
	(0.204)	(0.207)	(0.287)	(0.288)	(0.158)	(0.169)	(0.208)	(0.226)
ΔDuty × HOMOGENEOUS		1.528***		1.342***		1.289***		0.427
		(0.338)		(0.396)		(0.345)		(0.331)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	37,175	37,175	37,175	37,175	33,297	33,297	20,568	20,568
R-squared	0.0024	0.0029	0.0025	0.0028	0.0021	0.0025	0.0028	0.0029
Panel B: dependent variable = $\Delta\ln(p_{fhct})$								
ΔDuty	-0.134	-0.192	-0.362	-0.383	-0.262**	-0.351***	-0.254*	-0.299**
	(0.150)	(0.152)	(0.272)	(0.274)	(0.125)	(0.136)	(0.140)	(0.148)
ΔDuty × HOMOGENEOUS		1.406***		1.538***		1.141***		0.430
		(0.285)		(0.334)		(0.330)		(0.293)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Controls	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	70,665	70,665	48,899	48,899
R-squared	0.0022	0.0025	0.0022	0.0026	0.0022	0.0024	0.0029	0.0029

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment). By construction, tariff measure 3 yields fewer observations in the sample; tariff measure 4 provides fewest observations and thus presents the smallest sample size.

negative. This result is consistent with the literature that lower output tariffs can increase productivity by inducing tougher competition (e.g., Amiti and Konings, 2007) and thus increase prices according to the quality-and-trade literature (e.g., Hallak, 2010; Kugler and Verhoogen, 2012; Johnson, 2012, among others). When we regress the price change on industry input tariffs (see columns 2 and 6), the coefficients on input tariff are also significantly negative, implying that lower input tariffs can raise export prices through quality effect. When we include both input and output tariff as explanatory variables, the effect of input tariff, the key variable of our interest, is still significantly negative (see columns 3 and 7), which further confirms Proposition 1 that input tariff reductions raise export prices. Lastly, we estimate equation (22) with industry input tariff in columns 4 and 8. As expected, the coefficients on input tariff are significantly negative, while the coefficients on the interaction terms are significantly positive, confirming Propositions 1 and 2 that prices significantly increase with tariff reductions under the heterogeneous-quality case while under the homogeneous-quality case the price increase is significantly smaller. Thus, adopting industry-level tariffs does not alter our results.

Table 11: Industry Input and Output Tariffs

	Industry Input/Output Tariff							
	Dependent variable: $\Delta \ln(p_{fhct})$				Dependent variable: $\Delta \ln(p_{fht})$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \text{Duty}^{output}$	-0.418*		0.492		-0.800***		0.076	
	(0.218)		(0.300)		(0.245)		(0.381)	
$\Delta \text{Duty}^{input}$		-1.567***	-2.084***	-1.639***		-1.722***	-1.799***	-1.759***
		(0.288)	(0.399)	(0.287)		(0.318)	(0.488)	(0.317)
$\Delta \text{Duty}^{input}$ × HOMOGENEOUS				1.325***				0.966*
				(0.407)				(0.566)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	37,175	37,175	37,175	37,175
R-squared	0.0023	0.0029	0.0029	0.0031	0.0026	0.0031	0.0031	0.0032

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the HS6 product level in parentheses, because we use the concordance between HS6 products and Chinese input-output sector to compute industry input/output tariffs. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

6.1.5 Instrumental Variable Estimation

Now, we address the issue of the potential endogeneity of tariff changes. We use two methods to conduct instrumental variable estimation and report the results in Table 12. In specifications 1-4, we employ the 1997 tariff level as the initial, fixed past level to instrument the changes in tariffs; in specifications 5-8, we use the one-year lag level to instrument the change, i.e., we use X_{t-1} to instrument $\Delta X_{(t+3)-t}$. Again, we report results for both firm-product-country prices in Panel A and firm-product prices in Panel B.

We also conduct several tests to verify the quality of the instruments. The first diagnostic statistic for assessing the strength of identification is based on a Langrange-Multiplier (LM) test for underidentification using the Kleibergen and Paap (2006) rk statistic, because in our econometric model, the error term is assumed to be heteroskedastic and thus the usual canonical correlation likelihood ratio test (Anderson, 1984) is invalid. The Kleibergen and Paap (2006) rk statistic is to test whether an instrument is relevant to an endogenous variable (i.e., the change in tariffs). The null hypothesis that the model is underidentified is rejected at the 0.1 percent significance level. The second diagnostic test we perform is the Kleibergen and Paap (2006) Wald statistic to check whether the instrument is weakly correlated with the endogenous variable. The Kleibergen and Paap (2006) Wald F-statistics provide strong evidence to reject the null hypothesis that the first stage is weakly identified at a highly significant level.

Table 12 clearly illustrates that in all specifications, the coefficients on the interaction terms (ΔDuty × $HOMOGENEOUS$) are significantly positive at 1 percent significance level; the coefficients on tariff change are all significantly negative at, at least, 10 percent significance level. This is consistent with the main predictions of our model that tariff reductions lead to higher export prices while this effect increases in product differentiation and thus, the homogeneous-quality goods have a smaller increase, or even a reduction, in their export prices.

Table 12: Instrumental Variable Estimation

	instrumented by (initial, fixed) past level				$\Delta X_{(t+3)-t}$ instrumented by $X_{(t-1)}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: dependent variable $= \Delta \ln(p_{fhct})$								
ΔDuty	-0.784***	-0.734***	-1.040***	-0.991***	-0.604**	-0.576*	-0.950***	-0.921***
	(0.284)	(0.282)	(0.292)	(0.290)	(0.303)	(0.298)	(0.313)	(0.309)
ΔDuty ×*HOMOGENEOUS*			2.860***	2.872***			2.584***	2.587***
			(0.440)	(0.441)			(0.393)	(0.394)
Kleibergen-Paap rk LM χ^2 statistic	258.238†	255.854†	263.613†	260.625†	243.072†	240.731†	262.796†	259.269†
Kleibergen-Paap rk Wald F statistic	324.804†	316.071†	166.567†	161.578†	236.129†	240.943†	123.200†	126.014†
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736	79,736	79,736	79,736
R-squared	0.0014	0.0018	0.0009	0.0013	0.0016	0.0020	0.0012	0.0016
Panel B: dependent variable $= \Delta \ln(p_{fht})$								
ΔDuty	-1.004***	-0.879***	-1.279***	-1.155***	-0.763**	-0.682*	-1.143***	-1.061***
	(0.331)	(0.331)	(0.334)	(0.334)	(0.357)	(0.352)	(0.362)	(0.358)
ΔDuty × HOMOGENEOUS			2.741***	2.735***			2.514***	2.491***
			(0.461)	(0.461)			(0.411)	(0.410)
Kleibergen-Paap rk LM χ^2 statistic	320.491†	328.496†	277.530†	283.440†	293.122†	299.494†	291.961†	298.626†
Kleibergen-Paap rk Wald F statistic	479.218†	476.711†	192.023†	192.070†	325.660†	328.584†	162.740†	164.234†
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	37,175	37,175	37,175	37,175	37,175	37,175	37,175	37,175
R-squared	0.0012	0.0021	0.0013	0.0021	0.0015	0.0023	0.0016	0.0023

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. $\dagger$ indicates significance of p-value at the 0.1 percent level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

6.2 Export Prices and Quality Revisited

In this subsection, we test Propositions 3 and 4 to confirm the effect of tariff reductions on export prices and quality depends on import dependence and technology upgrading.

Effect of Import Dependence.—Proposition 3 states that the effect of a reduction in import tariff on export prices and quality is more significant for firms exhibiting greater increase in import dependence.

Table 13: Effect of Import Dependence

	Measures of Import Dependence					
	(i)		(ii)		(iii)	(iv)
	(1)	(2)	(3)	(4)	(5)	(6)
	$\#(\text{HS6})_{imp}$	$\#(\text{HS6-C})_{imp}$	$\frac{\#(\text{HS6})_{imp}}{\#(\text{HS6})_{exp}}$	$\frac{\#(\text{HS6-C})_{imp}}{\#(\text{HS6-C})_{exp}}$	Value_{imp}	Ratio_{imp}
Panel A: Dependent variable $= \Delta\ln(p_{fht})$						
ΔDuty $\times MORE\_IMP$	-0.507**	-0.414*	-0.408**	-0.535**	-0.584***	-0.430**
	(0.226)	(0.221)	(0.196)	(0.215)	(0.212)	(0.211)
ΔDuty $\times LESS\_IMP$	-0.313	-0.390*	-0.392*	-0.269	-0.203	-0.365*
	(0.194)	(0.203)	(0.230)	(0.206)	(0.208)	(0.206)
Year fixed effects	yes	yes	yes	yes	yes	yes
Observations	37,175	37,175	37,175	37,175	37,175	37,140
R-squared	0.0017	0.0016	0.0016	0.0017	0.0017	0.0016
Panel B: Dependent variable $= \Delta\ln(p_{fhct})$						
ΔDuty $\times MORE\_IMP$	-0.213	-0.209	-0.277**	-0.406***	-0.446***	-0.293*
	(0.157)	(0.153)	(0.137)	(0.155)	(0.164)	(0.171)
ΔDuty $\times LESS\_IMP$	-0.181	-0.182	-0.071	-0.010	-0.003	-0.128
	(0.141)	(0.147)	(0.166)	(0.140)	(0.132)	(0.129)
Year fixed effects	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736	79,669
R-squared	0.0019	0.0019	0.0019	0.0020	0.0020	0.0019
Panel C: Dependent variable $= \Delta\ln(quality_{fhct})$						
ΔDuty $\times MORE\_IMP$	-0.709***	-0.665***	-0.494***	-0.520***	-0.740***	-0.559**
	(0.198)	(0.199)	(0.173)	(0.199)	(0.219)	(0.226)
ΔDuty $\times LESS\_IMP$	-0.233	-0.254	-0.375*	-0.383**	-0.222	-0.367**
	(0.181)	(0.184)	(0.222)	(0.183)	(0.163)	(0.162)
Year fixed effects	yes	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736	79,669
R-squared	0.0012	0.0012	0.0011	0.0011	0.0012	0.0011

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. The sample size is relatively smaller in column 6 because some firms do not report the value of intermediate inputs and therefore those firms have missing values for the ratio of import value to total value of intermediate inputs.

To verify this proposition, we estimate the following equation and its variants:

$$\Delta\ln(p_{fh(c)t}) = \beta_1 \Delta Duty_{ft} \times MORE\_IMP_{ft} + \beta_2 \Delta Duty_{ft} \times LESS\_IMP_{ft} + \varphi_t + \epsilon_{fh(c)t}, \quad (23)$$

where $MORE\_IMP$ is a dummy variable which is equal to one for heavily-import-dependent firms and zero for less import-dependent firms, and $LESS\_IMP$ is a dummy variable which is equal to one for less import-dependent firms and zero for more import-dependent firms. Both dummy variables are firm specific. We use the median of import dependence measure to define more or less import-dependent firms. The measures of import dependence we use here are consistent with the four measures (see Table 3) in Section 3 of stylized facts. The only difference is now we use both HS6 and HS6-country to define variety when computing measures (i) and (ii), while in stylized facts we only use HS6 to define imported variety. Table 13 report estimation results of equation (23) and its variants. Panels A and B report the results with changes in prices at product level ($\Delta \ln(p_{fht})$) and product-destination level ($\Delta \ln(p_{fhct})$) as dependent variable, respectively. Panel C reports the results with changes in quality as regressand. If Proposition 3 is true, we expect to see a negative β_1 and the magnitude of β_1 should be larger than the magnitude of β_τ in the baseline regressions for export prices and quality (see column 5 in Table 5 for Panel A, column 3 in Table 5 for Panel B, and column 7 in Table 6 for Panel C). We also expect β_2 is less negative than β_1, implying that the price increase and quality upgrading is less significant for firms with smaller increase in their import dependence. The results in Table 13 are consistent with our expectations and therefore corroborate Proposition 3.

Table 14: Effect of Technology Upgrading

	Approaches to Estimating TFP				
	(1) O-P	(2) VA	(3) OLS	(4) L-P	(5) ACF-OP
Panel A: Dependent variable $= \Delta \ln(p_{fht})$					
ΔDuty $\times HIGH\Delta TFP$	-0.623***	-0.629***	-0.609***	-0.687***	-0.572***
	(0.218)	(0.228)	(0.213)	(0.226)	(0.218)
ΔDuty $\times LOW\Delta TFP$	-0.174	-0.194	-0.182	-0.148	-0.218
	(0.204)	(0.195)	(0.209)	(0.198)	(0.205)
Year fixed effects	yes	yes	yes	yes	yes
Observations	37,175	37,175	37,175	37,175	37,175
R-squared	0.0018	0.0017	0.0017	0.0018	0.0017
Panel B: Dependent variable $= \Delta \ln(p_{fhct})$					
ΔDuty $\times HIGH\Delta TFP$	-0.247*	-0.224*	-0.245*	-0.316**	-0.230*
	(0.135)	(0.134)	(0.133)	(0.136)	(0.135)
ΔDuty $\times LOW\Delta TFP$	-0.117	-0.153	-0.118	0.010	-0.143
	(0.180)	(0.177)	(0.183)	(0.191)	(0.176)
Year fixed effects	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736
R-squared	0.0019	0.0019	0.0019	0.0019	0.0019
Panel C: Dependent variable $= \Delta \ln(quality_{fhct})$					
ΔDuty $\times HIGH\Delta TFP$	-0.502***	-0.471**	-0.542***	-0.598***	-0.511***
	(0.180)	(0.186)	(0.178)	(0.180)	(0.182)
ΔDuty $\times LOW\Delta TFP$	-0.364	-0.413*	-0.301	-0.190	-0.352
	(0.228)	(0.213)	(0.234)	(0.245)	(0.225)
Year fixed effects	yes	yes	yes	yes	yes
Observations	79,736	79,736	79,736	79,736	79,736
R-squared	0.0011	0.0011	0.0011	0.0012	0.0011

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term.

Effect of Technology Upgrading.—Proposition 4 states that the effect of a reduction in import tariff on optimal quality and export prices is more significant for firms upgrading their technology. We estimate the following equation and its variant (with quality as regressand):

$$\Delta \ln(p_{fh(c)t}) = \beta_1 \Delta Duty_{ft} \times HIGH\Delta TFP_{ft} + \beta_2 \Delta Duty_{ft} \times LOW\Delta TFP_{ft} + \varphi_t + \epsilon_{fh(c)t}, \quad (24)$$

where $HIGH\Delta TFP$ is a dummy variable which is equal to one for firms with greater increase in their productivity and zero otherwise, and $LOW\Delta TFP$ is a dummy variable which is equal to one for firms with smaller increase in productivity and zero otherwise.

Table 14 reports results of equation 24. Panels A, B, and C present results based on different dependent variables to capture changes in export prices at either product level or product-destination level and changes in estimated quality. Different columns correspond to different approaches to estimating TFP. If Proposition 4 is true, we expect to see a more significantly negative β_1 and the magnitude of β_1 should be larger than the magnitude of β_τ in the baseline regressions for export prices and quality (see column 5 in Table 5 for Panel A, column 3 in Table 5 for Panel B, and column 7 in Table 6 for Panel C). We also expect a more negative and significant β_1 and a less negative and less significant (or nonsignificant) β_2, implying that firms with greater technology upgrading have more significant effect of tariff reductions on their export prices and quality. The results in Table 14 are fully consistent with our expectations and, hence, support Proposition 4.

7 Robustness

We conduct five robustness checks. First, we provide more cross-sectional evidence about the relationship between tariffs and export prices. Second, we present results with different-period difference estimation. Third, we show that our results regarding the price increase are not sensitive to currency appreciation. Fourth, we use processing exporters as comparison group to show that our quality upgrading mechanism is specific to ordinary exporters because processing trade firms do not pay tariffs. Last, but not least, we confirm that our results are not biased towards big firms using the whole customs data without matching to the manufacturing firm survey.

7.1 Cross-sectional Pattern with Industry Tariffs

To provide more evidence on the relationship between tariffs and export prices, we also conduct the baseline regression in levels (see equation (17)) with industry input/output tariffs to present the cross-sectional patterns in Table 15.[32] Columns 1-3 and 4-6 present the results with export prices for HS6-country product and HS6 product, respectively. The results are similar to the previous long-difference estimation results in Table 11: in separate regressions, the coefficients on output tariffs and

[32]We present the cross-sectional pattern with industry- instead of firm-specific tariffs because we do not have theoretical justification of firm-specific tariffs. Our theoretically derived firm-specific measures refer to tariff reductions at the firm level.

on input tariffs are both significantly negative (see columns 1-2 and 4-5); in combined regressions, the effect of input tariffs are still significantly negative (see columns 3 and 6). As input tariff is of our interest, this further provides evidence on the negative relationship between the levels of export prices and the levels of input tariffs, i.e., cross-sectionally speaking, higher export prices are also associated with lower input tariffs.

Table 15: Regressions in Levels with Industry Input/Output Tariffs

	Industry Input/Output Tariff					
	Dependent variable: $\ln(p_{fhct})$			Dependent variable: $\ln(p_{fht})$		
	(1)	(2)	(3)	(4)	(5)	(6)
$Duty^{output}$	-0.409***		0.344***	-0.738***		0.046
	(0.087)		(0.115)	(0.145)		(0.196)
$Duty^{input}$		-1.457***	-1.814***		-1.633***	-1.678***
		(0.137)	(0.182)		(0.209)	(0.283)
Year fixed effects	yes	yes	yes	yes	yes	yes
Firm-product-country fixed effects	yes	yes	yes			
Firm-product fixed effects				yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes
Observations	1,161,028	1,161,028	1,161,028	420,034	420,034	420,034
R-squared	0.981	0.981	0.981	0.969	0.969	0.969

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI) at the 4-digit CIC industry in China. Firm-level controls include TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

Table 16: Results with Different-period Difference

	Dependent Variable					
	$\Delta\ln(ExportPrice)_{fhct}$			$\Delta\ln(ExportPrice)_{fht}$		
	(1)	(2)	(3)	(4)	(5)	(6)
In 2 period difference: $\Delta Duty_{t-(t-2)}$	-0.180*			-0.255*		
	(0.108)			(0.137)		
In 4 period difference: $\Delta Duty_{t-(t-4)}$		-0.271*			-0.468**	
		(0.153)			(0.200)	
In 5 period difference: $\Delta Duty_{t-(t-5)}$			-0.487**			-0.669**
			(0.222)			(0.290)
Year fixed effects	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes
Observations	158,616	37,427	14,504	69,040	18,483	7,624
R-squared	0.0015	0.0008	0.0006	0.0013	0.0012	0.0009

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

7.2 Results in Various Period Difference

In our main results, we report the long-difference estimation results in 3 period difference. To show our results are robust to different period difference, we also conduct estimation in various period difference. The results are reported in Table 16. When we use 2-year, 4-year, or 5-year difference, all coefficients on $\Delta Duty$ are still significantly negative, consistent with our main results. When we use 1-year difference, the coefficients on $\Delta Duty$ are also negative but nonsignificant, probably because that one year is too short for firms to adjust quality and prices, and therefore are not included in Table 16.

7.3 Sensitivity to Currency Appreciation

Our main results show that export prices increase with tariff reductions in China. Note that our export price is denominated in US dollar. However, one may be concerned that the price increase is partially due to the appreciation of *Renminbi* (Chinese currency, hereafter RMB). It is possible that a stronger RMB reduces firms' costs to purchase imported inputs with local currency, and thus provides firms more incentive to switch to better inputs. To test the sensitivity of our results to RMB appreciation, we also use the data during the period before the appreciation to test whether export prices indeed increase without currency appreciation. As RMB appreciated in late 2005, we dropped data of 2005 and 2006, and conduct the long-difference estimation of equation (18) and its variants for only one period, i.e., 2004-2001. Consequently, we have a smaller sample size and less significant level, and the year fixed effect term is also omitted. Table 17 reports the results and all coefficients on $\Delta Duty$ are negative, consistent with Proposition 1.

Table 17: Results in Pre-Appreciation Periods (2004-2001)

	Dependent Variable					
	Δ ln(Export Price$_{fhc}$)		Δ ln(Export Price$_{fh}$)		ΔExport Price Index$_f$	
Regressor:	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-0.110	-0.114	-0.424**	-0.422**	-0.289*	-0.288*
	(0.118)	(0.118)	(0.179)	(0.179)	(0.174)	(0.170)
Industry-level Competition Control		yes		yes		yes
Firm-level Controls		yes		yes		yes
Observations	18,809	18,809	9,253	9,253	2,855	2,855
R-squared	0.0001	0.0008	0.0005	0.0012	0.0005	0.0026

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in 2001 at the 4-digit CIC industry in China. Firm-level controls include the changes between 2004 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

Table 18: Comparison Group: Pure Processing Exporters

	Dependent Variable					
	Δ ln(Export Price$_{fhc}$)		Δ ln(Export Price$_{fh}$)		ΔExport Price Index$_f$	
Regressor:	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	0.023	0.105	-0.061	-0.058	-0.150	-0.176
	(0.201)	(0.180)	(0.215)	(0.216)	(0.133)	(0.133)
Year fixed effects	yes	yes	yes	yes	yes	yes
Industry-level Competition Control		yes		yes		yes
Firm-level Controls		yes		yes		yes
Observations	8,662	8,662	4,891	4,891	1,761	1,761
R-squared	0.0059	0.0068	0.0051	0.0058	0.0151	0.0266

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (t-3) at the 4-digit CIC industry in China. Firm-level controls include the changes between year t and year (t-3) in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

7.4 Comparison Group: Processing Exporters

We use processing exporters as comparison group to show that processing firms do not significantly increase export prices, probably because they never pay tariffs to begin with. As some firms are "hybrid" exporters, i.e., they do both ordinary trade and processing trade transactions, we only select those pure processing exporters as comparison. Table 18 reports the results of equation (18) for those pure processing firms, which can be compared with the baseline regressions for ordinary exporters in Table 5. Now all coefficients on $\Delta Duty$ become nonsignificant, and sometimes the signs are even positive. This suggests that our quality upgrading mechanism fits ordinary exporters as they pay import tariffs.

7.5 Large Sample Test Using Whole Customs Data

So far our empirical results are based on the merged data built upon the NBSC manufacturing survey database and the Customs database. However, the NBSC manufacturing survey only includes above-scale firms, which may lead to sample selection bias. Therefore, to further verify that our results are not biased towards big firms, we replicate baseline regressions with both firm-specific tariff reductions and industry input tariff reductions in Table A.3 in Appendix, where columns 1-6 present results of export prices for HS6-country product and columns 7-12 report results of export prices at HS6 level. In each of the six columns, the first five columns correspond to firm-specific measures of tariff reductions and the last one corresponds to industry input tariff reduction measure. Among the five columns of using firm-specific measures of tariff reductions, the first one adopts our main tariff reduction measure, following equation (16), and the rest four employ the four alternative measures of tariff reductions as described in order in Section 5.2. In Table A.3, all coefficients on the interaction terms ($\Delta Duty\times\ HOMOGENEOUS$) are significantly positive and most coefficients on $\Delta Duty$ are significantly negative. This fully supports the main predictions of our model that firms increase export prices with tariff reductions when quality is heterogeneous but may decrease prices when quality is homogeneous (see Propositions 1 and 2).

[Insert Table A.3 here]

We also plot the price distribution based on the whole customs data in Figure 7 to confirm the different patterns of price change by product differentiation. Similar as Figure 2 based on the merged data in stylized facts, the price distribution apparently shifts to the right for differentiated goods in Panel A, while this price shifting pattern is nonsignificant or even reversed for homogeneous goods in Panel B.

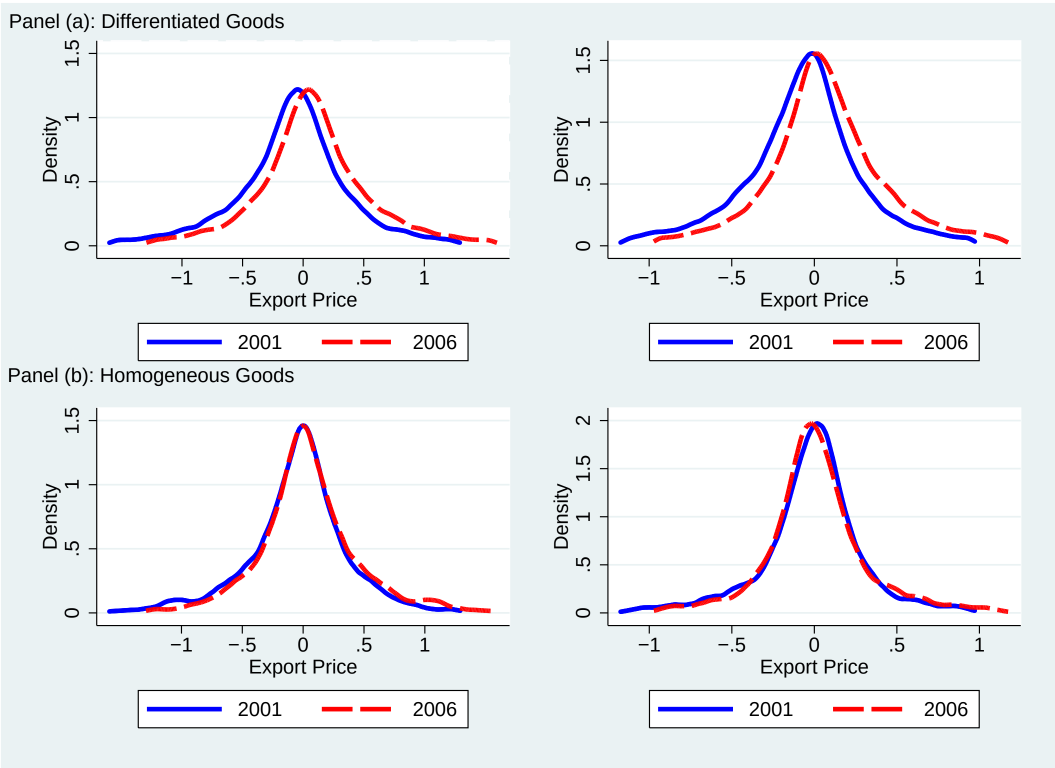

Figure 7: Distribution of Export Prices Based on Whole Customs Data (2001 vs. 2006)
Note: The graphs in the left and the right columns refer to HS6 and HS6-country product, respectively.

8 Conclusion

In this paper, we extend Melitz's (2003) model of trade with heterogeneous firms by introducing endogenous product quality, endogenous technology upgrading, and endogenous number of imported varieties. In order to analyze how quality effect of trade liberalization affect export prices, this paper builds a unified framework to analyze both cases of heterogeneous quality and homogeneous quality.

The model predicts that when quality is heterogeneous, a reduction in import tariff induces firms to choose higher product quality and set higher export prices, and this effect is less significant or even opposite when quality is homogeneous. Taking into account the endogenous firm decisions on technology upgrading and imported varieties increase the effect of trade liberalization on export prices. All those predictions are consistent with the stylized facts based on Chinese data and also verified by different estimation specifications.

Therefore, we conclude that quality effect is indeed an important channel of the impact of trade liberalization on export prices. Furthermore, firms respond to trade liberalization through their endogenous decisions on imported set and technology upgrading. Those responses to trade liberalization amplify the quality effect mechanism.

There are undoubtedly some limitations to our present study. Like De Loecker et al. (2012), price is multiplication of markup and marginal cost. Hence, it is noteworthy to analyze how trade liberalization affects markup and marginal cost when markup is endogenous. The quality effect of trade liberalization on export price can come from two different sources. On one hand, higher-quality product may yield higher markup due to its greater market power. On the other hand, higher-quality product also incurs higher marginal cost. Then, which one accounts more in explaining the quality effect of trade liberalization on export price? It would be interesting to further decompose the quality effect into the change in markup and the change in marginal cost, which is left for future research. However, one would expect that tariff reductions imply lower prices (via both lower marginal costs and lower markups) if quality was exogenous. Here, markups decrease due to pro-competitive effects of trade liberalization (Melitz and Ottaviano, 2008). Therefore, introducing endogenous markup would potentially *amplify* our mechanism of quality adjustment. The reason is twofold: First, when quality is heterogeneous a reduction in import tariffs would increase export prices (via both higher marginal costs and higher markups). Second, when quality is homogeneous a reduction in import tariffs would decrease export prices (via both lower marginal costs and lower markups).

References

Ackerberg, Daniel, Kevin Caves, and Garth Frazer, "Structural identification of production functions," MPRA Paper 38349, University Library of Munich, Germany December 2006.

Ahn, JaeBin, Amit K. Khandelwal, and Shang-Jin Wei, "The role of intermediaries in facilitating trade," *Journal of International Economics*, May 2011, *84* (1), 73–85.

Amiti, Mary and Amit K. Khandelwal, "Import Competition and Quality Upgrading," *The Review of Economics and Statistics*, May 2013, *95* (2), 476–490.

_ and Jozef Konings, "Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia," *American Economic Review*, December 2007, *97* (5), 1611–1638.

Anderson, James E. and Eric van Wincoop, "Trade Costs," *Journal of Economic Literature*, September 2004, *42* (3), 691–751.

Anderson, T. W., *An introduction to multivariate statistical analysis* Wiley series in probability and mathematical statistics, 2 ed., New York: Wiley, 1984. T.W. Anderson; ;25 cm; Includes index; Bibliography: p. 643-665.

Antoniades, Alexis, "Heterogeneous Firms, Quality and Trade," Unpublished Manuscript, Princeton University and Georgetown University November 2012.

Arkolakis, Costas, "Market Penetration Costs and the New Consumers Margin in International Trade," *Journal of Political Economy*, 2010, *118* (6), 1151 – 1199.

Baldwin, Richard and James Harrigan, "Zeros, Quality, and Space: Trade Theory and Trade Evidence," *American Economic Journal: Microeconomics*, May 2011, *3* (2), 60–88.

Bas, Maria, "Input-trade liberalization and firm export decisions: Evidence from Argentina," *Journal of Development Economics*, 2012, *97* (2), 481 – 493.

Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott, "Trade costs, firms and productivity," *Journal of Monetary Economics*, July 2006, *53* (5), 917–937.

_ , _ , and _ , "Importers, Exporters and Multinationals: A Portrait of Firms in the U.S. that Trade Goods," in "Producer Dynamics: New Evidence from Micro Data" NBER Chapters, National Bureau of Economic Research, Inc, 2009, pp. 513–552.

Brandt, Loren, Johannes Van Biesebroeck, and Yifan Zhang, "Creative Accounting or Creative Destruction? Firm-level Productivity Growth in Chinese Manufacturing," *Journal of Development Economics*, 2012, *97* (2), 339–351.

Broda, Christian and David E. Weinstein, "Globalization and the Gains From Variety," *The Quarterly Journal of Economics*, 2006, *121* (2), 541–585.

Bustos, Paula, "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, February 2011, *101* (1), 304–40.

Cai, Hongbin and Qiao Liu, "Competition and Corporate Tax Avoidance: Evidence from Chinese Industrial Firms," *Economic Journal*, 04 2009, *119* (537), 764–795.

De Loecker, Jan, Pinelopi K. Goldberg, Amit K. Khandelwal, and Nina Pavcnik, "Prices, Markups and Trade Reform," Unpublished manuscript August 2012.

Fan, Haichao, Edwin L.-C. Lai, and Yao Amber Li, "Credit Constraints, Quality, and Export Prices: Theory and Evidence from China," MPRA Paper 40857, University Library of Munich, Germany August 2012.

Feenstra, Robert C and James R Markusen, "Accounting for growth with new inputs," *International Economic Review*, 1994, pp. 429–447.

— , Zhiyuan Li, and Miaojie Yu, "Exports and credit constraints under incomplete information: Theory and evidence from china," *Review of Economics and Statistics*, forthcoming.

Feng, Ling, Zhiyuan Li, and Deborah L. Swenson, "The Connection between Imported Intermediate Inputs and Exports: Evidence from Chinese Firms," Working Paper 18260, National Bureau of Economic Research July 2012.

Fernandes, Ana M., "Trade policy, trade volumes and plant-level productivity in Colombian manufacturing industries," *Journal of International Economics*, March 2007, *71* (1), 52–71.

Ge, Ying, Huiwen Lai, and Susan Zhu, "Intermediates Import and Gains from Trade Liberalization," Technical Report, mimeo, University of International Business and Economics 2011.

Gervais, Antoine, "Product Quality and Firm Heterogeneity in International Trade," Working Papers 13-08, Center for Economic Studies, U.S. Census Bureau March 2013.

Goldberg, Pinelopi Koujianou, Amit Kumar Khandelwal, Nina Pavcnik, and Petia Topalova, "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India," *The Quarterly Journal of Economics*, November 2010, *125* (4), 1727–1767.

Gopinath, Gita and Brent Neiman, "Trade Adjustment and Productivity in Large Crises," NBER Working Papers 16958, National Bureau of Economic Research, Inc April 2011.

— and — , "Trade Adjustment and Productivity in Large Crises," *American Economic Review*, forthcoming.

Hallak, Juan Carlos, "A Product-Quality View of the Linder Hypothesis," *The Review of Economics and Statistics*, 09 2010, *92* (3), 453–466.

— and Jagadeesh Sivadasan, "Firms' Exporting Behavior under Quality Constraints," Unpublished Manuscript, University of Michigan 2011.

Halpern, László, Miklós Koren, and Adam Szeidl, "Imported Inputs and Productivity," CeFiG Working Papers 8, Center for Firms in the Global Economy September 2011.

Head, Keith and John Ries, "Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade," *American Economic Review*, September 2001, *91* (4), 858–876.

İşcan, Talan, "Trade liberalisation and productivity: a panel study of the Mexican manufacturing industry," *The Journal of Development Studies*, 1998, *34* (5), 123–148.

Johnson, Robert C., "Trade and prices with heterogeneous firms," *Journal of International Economics*, 2012, *86* (1), 43 – 56.

Kasahara, Hiroyuki and Joel Rodrigue, "Does the use of imported intermediates increase productivity? Plant-level evidence," *Journal of Development Economics*, August 2008, *87* (1), 106–118.

Khandelwal, Amit K., Peter K. Schott, and Shang-Jin Wei, "Trade Liberalization and Embedded Institutional Reform: Evidence from Chinese Exporters," *American Economic Review*, forthcoming.

Kleibergen, Frank and Richard Paap, "Generalized reduced rank tests using the singular value decomposition," *Journal of Econometrics*, July 2006, *133* (1), 97–126.

Krishna, Pravin and Devashish Mitra, "Trade liberalization, market discipline and productivity growth: new evidence from India," *Journal of Development Economics*, August 1998, *56* (2), 447–462.

Kugler, Maurice and Eric Verhoogen, "Prices, Plant Size, and Product Quality," *Review of Economic Studies*, 2012, *79* (1), 307–339.

Levinsohn, James and Amil Petrin, "Estimating Production Functions Using Inputs to Control for Unobservables," *The Review of Economic Studies*, 2003, *70* (2), pp. 317–341.

Manova, Kalina and Zhihong Yu, "Firms and Credit Constraints along the Value Chain: Processing Trade in China," Unpublished Manuscript, Stanford University May 2013.

_ and Zhiwei Zhang, "Export Prices Across Firms and Destinations," *The Quarterly Journal of Economics*, 2012, *127*, 379–436.

_ and _ , "Multi-Product Firms and Product Quality," NBER Working Papers 18637, National Bureau of Economic Research, Inc December 2012.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, November 2003, *71* (6), 1695–1725.

_ and Gianmarco I. P. Ottaviano, "Market Size, Trade, and Productivity," *Review of Economic Studies*, 2008, *75* (1), 295–316.

Muendler, Marc-Andreas, "Trade, Technology, and Productivity: A Study of Brazilian Manufacturers, 1986-1998," Technical Report 2004.

Olley, G. Steven and Ariel Pakes, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 1996, *64* (6), pp. 1263–1297.

Pavcnik, Nina, "Trade Liberalization, Exit, and Productivity Improvement: Evidence from Chilean Plants," *Review of Economic Studies*, January 2002, *69* (1), 245–76.

Perla, Jesse, Christopher Tonetti, and Michael E. Waugh, "Equilibrium Technology Diffusion, Trade, and Growth," Mimeo, New York University December 2012.

Rauch, James E., "Networks versus markets in international trade," *Journal of International Economics*, June 1999, *48* (1), 7–35.

Romalis, John, "NAFTA's and CUSFTA's Impact on International Trade," *The Review of Economics and Statistics*, August 2007, *89* (3), 416–435.

Schor, Adriana, "Heterogeneous productivity response to tariff reduction. Evidence from Brazilian manufacturing firms," *Journal of Development Economics*, December 2004, *75* (2), 373–396.

Schott, Peter K., "Across-product Versus Within-product Specialization in International Trade," *The Quarterly Journal of Economics*, May 2004, *119* (2), 646–677.

Simonovska, Ina and Michael Waugh, "The Elasticity of Trade: Estimates and Evidence," Working Papers, University of California at Davis, Department of Economics 2013.

Smeets, Valerie and Frédèric Warzynski, "Estimating Productivity with Multi-product Firms, Pricing Heterogeneity and the Role of International Trade," *Journal of International Economics*, forthcoming.

Tang, Heiwai and Yifan Zhang, "Quality Differentiation and Trade Intermediation," Technical Report 2012.

Topalova, Petia and Amit Khandelwal, "Trade Liberalization and Firm Productivity: The Case of India," *The Review of Economics and Statistics*, August 2011, *93* (3), 995–1009.

Trefler, Daniel, "The Long and Short of the Canada-U. S. Free Trade Agreement," *American Economic Review*, September 2004, *94* (4), 870–895.

Tybout, James, Jamie de Melo, and Vittorio Corbo, "The effects of trade reforms on scale and technical efficiency : New evidence from Chile," *Journal of International Economics*, November 1991, *31* (3-4), 231–250.

Verhoogen, Eric A., "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector," *The Quarterly Journal of Economics*, 05 2008, *123* (2), 489–530.

Waugh, Michael E., "International Trade and Income Differences," *American Economic Review*, December 2010, *100* (5), 2093–2124.

Yeaple, Stephen Ross, "A simple model of firm heterogeneity, international trade, and wages," *Journal of International Economics*, January 2005, *65* (1), 1–20.

Yu, Miaojie, "Processing Trade, Tarff Reductions, and Firm Productivity: Evidence from Chinese Products," Unpublished Manuscript, CCER at Peking University October 2011.

_ and Wei Tian, "Export Intensity and Input Trade Liberalization : Evidence from Chinese Firms," Working Paper, CCER at Peking University 2013.

A Appendix

A.1 Data Description

The process of our sample construction can be summarized by five steps:

1. We organize the export data from the Chinese Customs Database by the following procedure:

   1.1 We delete all trade intermediaries from exporting firms. Similar to Ahn et al. (2011) and Tang and Zhang (2012), we identify trade intermediaries by finding the presence of phrases (such as "trading", "exporting", and "importing") in their company names.[33] We further drop all exports under processing trade regime and only keep ordinary trade in our sample.[34]

   1.2 We drop all observations with no destination information or destination country reported as PRC China. We further drop all observations with zero or missing quantity or value.

   1.3 We use the conversion table from the UN Comtrade to convert the HS 2002 codes into the HS 1996 codes at HS 6-digit level. Then we aggregate the export value and export quantity for each product at either HS6 or HS6-destination.

   1.4 We deflate the export value using output deflators from Brandt et al. (2012).[35] Note that the deflators in Brandt et al. (2012) are by 4-digit CIC industry in China, while there is no information about CIC industry code in the Customs Data. Therefore, we use the concordance between the Input-Output (I-O) sectors and the HS codes and the concordance between the I-O sectors and the CIC industries by the NBSC to merge each HS code with a CIC industry. Eventually, we are able to compute the deflated value at HS6 level.

   1.5 We estimate product quality and quality-adjusted price by following Khandelwal et al. (forthcoming). See Section 6.1.2 for details.

   1.6 We merge the above sample with Rauch's product classification (Rauch, 1999) to divide sample into differentiated goods and homogeneous goods.

2. We organize the import data from the Chinese Customs Database by the following procedure:

   2.1-2.3 are similar with 1.1-1.3.

   2.4 We deflate the import value using input deflators from Brandt et al. (2012). The process is similar to Step 1.4.

   2.5 We merge import data with import tariff at HS6 level and compute different measures of the effective import tariff reduction faced by each firm. See Section 5.2 for more details of each tariff measure.

[33] As company names in the Customs Database are written in Chinese, we search for "mao yi", "wai mao", "wai jing", "jin chu kou", "jing mao", "gong mao", and "ke mao" in firm names.

[34] Move 1.1 after 1.5 does not alter our estimation results.

[35] The deflator data are downloaded from http://www.econ.kuleuven.be/public/N07057/China/.

3. We merge the export data (based on Step 1) and the import data (based on Step 2) together to obtain a large sample based on the Customs Database solely. This sample serves as the basis for the robustness check when we use the whole customs data.

4. To compute firm TFP, we merge the above sample based on customs data with the NBSC manufacturing firm survey data. Our matching procedure is done in three steps: (1) by company name, (2) by telephone number and zip code, and (3) by telephone number and contact person name together (see detailed description of the matching process in Fan et al., 2012). The matching rates are reported in Section 2.

5. We further delete some unsatisfactory observations and outliers according to the following criteria in Cai and Liu (2009) and the General Accepted Accounting Principles, due to mis-reporting by some firms in the NBSC database: (i) the total assets must be higher than the liquid assets; (ii) the total assets must be larger than the total fixed assets; (iii) the total assets must be larger than the net value of the fixed assets; (iv) a firm's identification number cannot be missing and must be unique; and (v) the established time must be valid.

A.2 Endogenous Decisions on Imports and Technology Upgrading

In order to prove the "amplification effect", i.e., import dependence and technology upgrading would amplify the effect of tariff reductions on export prices and quality, we need to derive how import varieties and technology upgrading depend on import tariffs. We thus slightly modify the set-up of modeling technology. In the main model in Section 4, the initial productivity ϕ is assumed to be drawn from a certain distribution, which is exogenously given. Now we assume this productivity parameter, ϕ, is realized after a firm's decision on whether or not to upgrade its technology. Then, the original "initial" productivity is still assumed to be drawn from a common distribution and denoted by $\widetilde{\phi}$.

After observing their original initial productivity $\widetilde{\phi}$, firms can choose to increase their productivity by paying a fixed technology upgrading cost, as in Yeaple (2005) and Bustos (2011), or, to remain their original initial productivity. Hence, we express the new idiosyncratic component of productivity, ϕ, by:

$$\phi = \begin{cases} \gamma\widetilde{\phi} & , \text{ if adopting technology upgrading;} \\ \widetilde{\phi} & , \text{ otherwise,} \end{cases} \tag{25}$$

where $\widetilde{\phi}$ is exogenously given, firm-specific, original initial productivity, and $\gamma > 1$ is a constant term. After the original initial productivity draw, firms can choose to upgrade their technology by γ times if they decide to pay an additional fixed cost consisting of f units of labor. Hence, whether to upgrade technology is an endogenous decision for the firm.

Now under this new set-up with the possibility of upgrading technology, given the imported inputs set Ω and productivity ϕ, a firm's profit optimization problem becomes:

$$\max_{p,q} \ (p - cq^{\alpha})\, q^{\sigma-1} \frac{p^{-\sigma}}{P^{1-\sigma}} S - f_m |\Omega|^{\lambda} - f_d q^{\beta} - I_{\gamma} f + Z \left[(p - cq^{\alpha})\, q^{\sigma-1} \frac{p^{-\sigma}}{P^{1-\sigma}} S - f_x \right] \tag{26}$$

where I_{γ} is an indicator function equalling one if the firm upgrades its technology, and zero otherwise; all other parameters have the same meaning as in equation (9) in the main model. Solving this optimization problem with respect to price p and quality choice q yields the same results as in Section 4.3.1. Next, we derive how the imported inputs set Ω and productivity ϕ are affected by import tariffs. For simplicity, we assume that after observing the original initial productivity $\widetilde{\phi}$, a firm decides its imported inputs set, Ω, and whether to upgrade technology simultaneously. This simultaneity assumption enables us to derive the firm's endogenous decisions on imported varieties given productivity and what types of firms would decide to upgrade technology given imported inputs. To derive the endogenous choice of imports and technology upgrading by firm, we assume that tariff τ_h is constant across products within a firm because now our interest is the firm-level choice and, for simplicity, we ignore the difference of product-level tariff within firm hereafter.

A.2.1 The Values and Varieties of Imports (Given Productivity)

This subsection characterizes the firm's decision on import values and import varieties. When a firm decides its imported inputs set, its technology ϕ could be viewed as given. Then, the revenue of a firm with the set of imported varieties Ω is given by:

$$R(\Omega, \phi, \tau) = \Lambda^{1-\frac{\beta}{\alpha}\Psi} \left[\left(\frac{\sigma}{\sigma - 1} \right) c \right]^{-\frac{\beta(\sigma-1)}{\alpha}\Psi} \left[\frac{(1+Z)S}{P^{1-\sigma}} \right]^{\frac{\beta}{\alpha}\Psi} \tag{27}$$

Then, the optimal expenditure on the imported varieties, E, can be derived as:

$$E(\Omega, \phi, \tau) = \left(\frac{P_M^{1-\varsigma}}{P_Z^{1-\varsigma} + P_M^{1-\varsigma}} \right) \left[\frac{(\sigma-1)\mu}{\sigma} \right] R(\Omega, \phi, \tau) \tag{28}$$

Expression (28) illustrates that the optimal expenditure on the imported input varieties decreases in import tariff τ. This stems from two parts: (i) a reduction in import tariff induces firms to produce higher-quality products and to achieve a higher revenue; (ii) a reduction in import tariff induces firms to spend more on the foreign intermediate inputs.

As the set of imported varieties is denoted by Ω, we use Ω^* to denote the optimal set of imported varieties. The optimal import decision of the firm is then to maximize profits net of the cost of importing foreign varieties:

$$\begin{aligned} \Omega^* &= \arg\max_{\Omega} \left\{ \Pi(\Omega, \phi, \tau) - f_d q^{\beta} - f_x - f_m |\Omega|^{\lambda} - I_{\gamma} f \right\} \\ &= \arg\max_{\Omega} \left\{ \frac{\alpha}{\sigma\beta\Psi} R(\Omega, \phi, \tau) - f_m |\Omega|^{\lambda} \right\} \end{aligned}$$

where $\Pi(\Omega,\phi,\tau) = \frac{1}{\sigma}R(\Omega,\phi,\tau)$ are profits gross of the fixed costs, and $|\Omega|$ denotes the number of imported varieties. As long as the second order conditions for an interior solution for Ω are satisfied, it can be shown that Ω^* would expand with a lower τ: a reduction in import tariff induces firms to import more varieties. Firms facing a lower import tariff spend more on imported inputs, so they are more likely to cover the fixed importing cost and therefore to expand the set of imported varieties. Put in other words, as the expenditure on imported inputs increases, more varieties will be imported by the firm. Therefore, we have the following proposition regarding the firm's import decisions:[36]

Proposition 5. ***Firms facing lower import tariff (i) spend more on imported varieties and (ii) tend to import more varieties.***

A.2.2 Technology Upgrading (Given Import Decision)

This subsection examines the firm's decision on technology upgrading and what types of firms would upgrade their technology after trade liberalization. Note that under the simultaneity assumption now the set of imported varieties Ω could be viewed as given. Then, the exporting revenue of a firm is expressed by:

$$R_x(\Omega,\phi,\tau) = \Lambda^{1-\frac{\beta}{\alpha}\Psi}\left[\left(\frac{\sigma}{\sigma-1}\right)c\right]^{-\frac{\beta(\sigma-1)}{\alpha}\Psi}\left(\frac{S}{P^{1-\sigma}}\right)^{\frac{\beta}{\alpha}\Psi} \tag{29}$$

The exporting profits of a firm without technology upgrading (i.e., $\phi = \widetilde{\phi}$) are:

$$\pi_x(\Omega,\phi,\tau) = \frac{1}{\sigma}R_x(\Omega,\phi,\tau) - f_x \tag{30}$$

The exporting cutoff (ϕ^x) is defined by:

$$\pi_x(\Omega,\phi,\tau) = 0 \Leftrightarrow \frac{1}{\sigma}R_x(\Omega,\phi^x,\tau) = f_x \tag{31}$$

Note that the exporting cost is fixed for all firms while the exporting benefit is increasing in firm productivity. Hence, the firms with productivity above the cutoff ϕ^x would export.

Profits if exporting with technology upgrading are:

$$\pi_H(\Omega,\phi,\tau) = \frac{\alpha}{\sigma\beta\Psi}R(\Omega,\phi,\tau) - f_m|\Omega|^\lambda - f_x - f \tag{32}$$

Profits if exporting without technology upgrading are:

$$\pi_L(\Omega,\phi,\tau) = \frac{\alpha}{\sigma\beta\Psi}R(\Omega,\phi,\tau) - f_m|\Omega|^\lambda - f_x \tag{33}$$

where the subscript H denotes using high technology (i.e., with technology upgrading), and the sub-

[36] Gopinath and Neiman (forthcoming) shows that firms with better technology will import a larger measure of varieties and Halpern et al. (2011) derive a property of their model that firms with lower fixed costs import a greater number of varieties.

script L denotes using low technology (without upgrading). Then the technology adoption cutoff $\left(\phi^h\right)$ is defined by:

$$\pi_H(\Omega,\phi,\tau)=\pi_L(\Omega,\phi,\tau)\Leftrightarrow\frac{\alpha}{\sigma\beta\Psi}\left[\gamma^{\frac{\beta(\sigma-1)}{\alpha}\Psi}-1\right]R\left(\Omega,\phi^h,\tau\right)=f \tag{34}$$

The benefit of adopting technology upgrading is that the firm makes higher revenues through improving production efficiency. The cost of adopting technology upgrading is its fixed cost, f. Note that this cost is the same for all firms while the benefit is increasing in firm productivity. This is why technology upgrading choice is characterized by a cutoff productivity level ϕ^h above which all firms adopt technology upgrading.

By comparing equations (31) and (34), we can see that the parameter restriction required for $\phi^h>\phi^x$ is that the fixed technology-upgrading costs are higher enough relative to the fixed exporting costs:

$$\left(\frac{\phi^h}{\phi^x}\right)^{\frac{\beta(\sigma-1)}{\alpha}\Psi}=\left(\frac{\beta\Psi}{\alpha}\right)\frac{f}{2^{\frac{\beta}{\alpha}\Psi}\left[\gamma^{\frac{\beta(\sigma-1)}{\alpha}\Psi}-1\right]f_x}>1 \tag{35}$$

As in Bustos (2011), underlying initial productivity differences sort firms into three groups: the low productivity firms ($\widetilde{\phi}<\phi^x$) serve only the domestic market and use technology L; the median productivity firms ($\phi^x<\widetilde{\phi}<\phi^h$) serve both foreign and domestic markets but still use technology L (without adopting technology upgrading); the high productivity firms ($\widetilde{\phi}>\phi^h$) serve both foreign and domestic markets and adopt high technology. During trade liberalization, a reduction in import tariff in general increases firms' revenues, inducing low productivity firms to enter the exporting market and to adopt technology upgrading. Hence, trade liberalization lowers both the exporting cutoff (ϕ^x) and the technology upgrading cutoff (ϕ^h). Let the subscript 0 and 1 denote pre-liberalization and post-liberalization, respectively, and the sorting pattern presents that $\phi_1^x<\phi_1^h<\phi_0^x<\phi_0^h$. The parameter restrictions required to obtain such sorting pattern has been verified by Bustos (2011) using Argentinian firms data.

As we focus on existing exporters, we are interested in the group of firms that were already exporters before liberalization $\left(\widetilde{\phi}>\phi_0^x\right)$. Among them, those in the upper range of productivity $\left(\widetilde{\phi}>\phi_0^h\right)$ already adopted high technology before trade liberalization and remain their high productivity without further technology upgrading; while firms in the lower range of productivity $\left(\phi_0^x<\widetilde{\phi}<\phi_0^h\right)$ adopt technology upgrading only after trade liberalization, because the sorting pattern predicts $\phi_1^h<\phi_0^x$. Therefore, after trade liberalization, all previously existing exporters adopt high technology, but only those existing low productivity exporting firms experience technology upgrading. This yields the following proposition:

Proposition 6. ***A reduction in import tariff induces the existing exporting firms with lower initial productivity to adopt technology upgrading.***

This proposition predicts that among the existing exporting firms, less productive firms upgrade technology more after trade liberalization than those with higher initial productivity. This proposition is also consistent with a few recent studies. For example, Bustos (2011) predicts that the effect of tariffs on technology upgrading is highest in the upper-middle range of the firm-size distribution. Proposition 6 in our paper further confirms the right panel of the nonlinear relationship predicted by Bustos (2011) because we only focus on existing exporters and thus the least productive, non-exporting firms are already excluded in our analysis. Perla et al. (2012) develop a dynamic model of growth and trade, and also predict that in equilibrium low productivity firms choose to upgrade their technology. .

A.2.3 Empirical Evidence for Firm Decisions on Imports and Technology Upgrading

In this subsection, we test Propositions 5 and 6 on how trade liberalization affects firm decisions on imported varieties and technology upgrading.

Import Decisions.—Proposition 5 states that, given productivity, firms facing lower import tariffs spend more on imports and tend to import more varieties. Table A.1 reports estimation results to support Proposition 5. Specification 1 regresses the change in import value at firm level on firm-specific tariff reductions. Specifications 2 and 3 regress changes in import value per product by each firm on tariff reductions, where product is defined at HS6 and HS6-country level, respectively. Specifications 4 and 5 regress changes in the number of imported varieties by each firm on tariff reductions, where variety is also defined at HS6 and HS6-country level, respectively. All coefficients on ΔDuty are negative and most of them are significant, implying that a reduction in tariffs leads to more imports in terms of value and the number of imported varieties.

Table A.1: Tariff and Import Decisions

	Dependent Variable				
	$\Delta \ln(\text{Import Value})_{ft}$	$\Delta \ln(\text{Import Value per Product})_{ft}$		$\Delta \ln(\#\text{ Imported Varieties})_{ft}$	
	(1)	(2)	(3)	(4)	(5)
ΔDuty	-1.699**	-1.295*	-1.340*	-0.359	-0.404
	(0.752)	(0.722)	(0.698)	(0.312)	(0.307)
Year fixed effects	yes	yes	yes	yes	yes
Observations	11,456	11,456	11,456	11,456	11,456
R-squared	0.0093	0.0011	0.0013	0.0243	0.0266

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term.

Technology Upgrading.—We are interested in what types of firms are more likely to upgrade their technology after trade liberalization. According to Proposition 6, among the existing exporting firms, those with lower initial productivity adopt technology upgrading. To test Proposition 6, we estimate the following equation:

$$\Delta \ln(TFP)_{ft} = \beta_\tau \Delta Duty_{ft} + \beta_X \Delta Duty_{ft} \times TFP_{f(t-3)} + \varphi_t + \epsilon_{ft}, \tag{36}$$

The coefficient on the interaction term, β_X, is of our interest. Again, we expect a positive β_X and a negative β_τ, which implies that firms with higher initial TFP upgrade their technology less than firms with lower initial TFP. Table A.2 reports the estimation results of equation (36). All results are consistent with our expectation, indicating that firms with lower initial TFP have greater improvement in their productivity.

Table A.2: Tariff and Technology Upgrading

	Dependent variable=$\Delta \ln(TFP)_{ft}$				
	Approaches to Estimating TFP				
	(1) O-P	(2) VA	(3) OLS	(4) L-P	(5) ACF-OP
ΔDuty	-19.55***	-12.96***	-16.53***	-15.88***	-11.34***
	(2.630)	(2.588)	(3.945)	(3.838)	(1.796)
ΔDuty $\times TFP$	4.228***	3.123***	3.852***	2.901***	3.558***
	(0.719)	(0.768)	(1.103)	(0.835)	(0.744)
Year fixed effects	yes	yes	yes	yes	yes
Observations	11,456	11,456	11,456	11,456	11,456
R-squared	0.0580	0.0429	0.0504	0.0374	0.0490

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term.

A.3 Table for Large Sample Test Using Whole Customs Data

Table A.3: Results Based on Whole Customs Data

	dependent variable = $\Delta \ln(p_{fhct})$						dependent variable = $\Delta \ln(p_{fht})$					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A:												
ΔDuty	-0.125**	-0.143*	-0.363***	-0.230***	-0.222***	-0.856***	-0.152*	-0.229*	-0.753***	-0.352***	-0.329***	-0.974***
	(0.057)	(0.076)	(0.115)	(0.061)	(0.068)	(0.112)	(0.089)	(0.120)	(0.178)	(0.095)	(0.116)	(0.159)
ΔDuty × HOMOGENEOUS	0.868***	1.428***	1.696***	0.775***	0.828***	1.611***	0.969***	1.308***	1.531***	0.855***	0.635***	1.302***
	(0.107)	(0.144)	(0.164)	(0.118)	(0.168)	(0.185)	(0.172)	(0.202)	(0.225)	(0.197)	(0.235)	(0.259)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	267,141	267,141	267,141	243,112	158,927	267,165	154,809	154,809	154,809	142,362	81,394	154,835
R-squared	0.0013	0.0014	0.0015	0.0012	0.0014	0.0015	0.0012	0.0013	0.0014	0.0012	0.0011	0.0014
Panel B:												
ΔDuty	-0.125	-0.143	-0.363*	-0.230**	-0.222**	-0.856***	-0.152	-0.229	-0.753***	-0.352***	-0.329**	-0.974***
	(0.106)	(0.143)	(0.208)	(0.100)	(0.095)	(0.214)	(0.135)	(0.180)	(0.234)	(0.116)	(0.132)	(0.228)
ΔDuty × HOMOGENEOUS	0.868***	1.428***	1.696***	0.775***	0.828***	1.611***	0.969***	1.308***	1.531***	0.855***	0.635***	1.302***
	(0.287)	(0.194)	(0.216)	(0.261)	(0.194)	(0.222)	(0.187)	(0.237)	(0.266)	(0.200)	(0.201)	(0.256)
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	267,141	267,141	267,141	243,112	158,927	267,165	154,809	154,809	154,809	142,362	81,394	154,835
R-squared	0.0013	0.0014	0.0015	0.0012	0.0014	0.0015	0.0012	0.0013	0.0014	0.0012	0.0011	0.0014

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Panel A reports results with regular standard errors. Panel B reports results with robust standard errors corrected for clustering at firm level for firm-specific tariff reductions (see columns 1-5 and 7-11) and at HS6 product level for industry input tariff reductions (see columns 6 and 12) in parentheses.