TRADE LIBERALIZATION, QUALITY, AND EXPORT PRICES

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Abstract—This paper presents theory and evidence from disaggregated Chinese data that tariff reductions induce a country's producers to upgrade the quality of their exports. We first document stylized facts regarding the effect of trade liberalization on export prices. Next, we develop an analytic framework that relates a firm's choice of quality to its access to imported intermediates. In the model, a reduction in import tariffs induces a firm to increase export quality and raise its export price in industries where the scope for quality differentiation is large and lower its export price in industries where the scope is small. The predictions are consistent with the stylized facts and are highly robust econometrically.

I. Introduction

OVER the past twenty years many developing countries have abruptly and substantially lowered tariffs and scaled back other trade barriers. This policy change has created the opportunity to observe the extent to which trade barriers affect the behavior of individual firms. A rapidly growing literature shows that trade liberalization has led to a surge in imports of intermediate inputs and that the improved access to foreign-made inputs has had a large impact on firm productivity and the scope of product offerings at the firm level.[1] Given the transformative impact of trade liberalization on documented productivity, it is natural to consider the effect trade barriers may have had on firms' decisions regarding the quality of the products that they produce.

This paper asks whether lower tariffs on imported intermediates induce firms to upgrade the quality of the goods that they export. Such a link between trade liberalization and export quality is important because the production of high-quality goods is often viewed as a precondition for export success and economic development (Amiti & Khandelwal, 2013).[2] To address this question, we present theory and evidence from highly disaggregated Chinese-linked firm-level production data and customs data that tariff reductions induced Chinese exporters to upgrade the quality of the goods that they export, particularly in industries where the scope for quality variation is high. Chinese firms that enjoy the largest tariff reductions are observed to raise the prices of their exports to existing export markets and shift their export volumes geographically from countries where demand for high-quality goods is relatively weak to markets where demand for high-quality goods is strong.

We first document two stylized facts regarding the relationship between the arguably exogenous tariff reductions imposed on China by accession to the World Trade Organization (WTO) and the export prices for ordinary (nonprocessing) Chinese incumbent exporters. We show that in industries in which products are highly differentiated, firms raise their export prices in response to a fall in the tariffs they pay on imported inputs. In industries featuring primarily homogeneous goods, the pattern is ambiguous or even reversed: a reduction in imported intermediate tariffs results in lower prices.

We explain these facts in the context of a simple model of firm quality choice. The model generates linear equations that relate changes in the export prices charged by the firm and changes in the output quality produced by the firm to changes in the tariffs of the set of goods imported by the firm. Importantly, the magnitude (and potentially the sign) of the coefficient on import tariffs depends on the scope for quality heterogeneity within the industry.

We then estimate our model using panel data for Chinese firms over the period 2001 to 2006. The unilateral trade liberalization imposed on China as a condition for WTO accession provides a source of exogenous variation that allows us to estimate the impact of tariff reduction on firm export prices.[3] Another advantage of our data is that they allow us to create precise firm-level measures of import tariff reductions and so allow us to capture the true extent of within-industry heterogeneity in the size of the direct impact of trade liberalization on a firm's marginal costs.[4] By using long differences within firm-destination-product categories, we eliminate many potential sources of spurious correlation. We also address the potential endogeneity of firm-level import behavior using instrumental variables.

Our coefficient estimates confirm the main predictions of our model. First, firms that face larger reductions in the tariffs imposed on their imported inputs increase rather than decrease their export prices when the good in question is in an industry where the scope for quality differentiation is large but not when the exported good is in an industry where

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[1] For instance, greater access to foreign intermediate inputs has been associated with higher firm-level productivity (Amiti & Konings, 2007, among others) and other firm-level adjustments such as domestic product scope (e.g., Goldberg et al., 2010).

[2] Schott (2004) shows that international specialization is less about the industrial composition of a country's exports and is more about the level of quality of a fixed set of goods.

[3] As is well known, China has long enjoyed MFN treatment by major trading partners prior to joining the WTO. For some trading partners, the MFN treatment was somewhat precarious and so may have discouraged longer-term relationships between foreign partners and Chinese firms.

[4] For robustness, we also consider more conventional measures of tariff reduction using input-output table coefficients as weights. Doing so generates qualitatively similar results.

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the scope for quality differentiation is small. This result is robust to the inclusion of a wide range of time-varying firm controls, alternative measures of tariff liberalization, and controlling for the changes in markups. Importantly, the result does not obtain in a placebo sample of export processing firms that were never subjected to tariffs. In addition, we present indirect evidence at the extensive margin of quality upgrading: firms experiencing large reductions in tariffs on their imported intermediates tend to enter new markets with relatively high-priced goods and exit markets where prices tended to be low.

Our paper contributes to a vibrant literature that links improved access to imported intermediate inputs to superior firm performance. Dimensions along which superior performance has been measured include improved total factor productivity (Amiti & Konings, 2007; Kasahara & Rodrigue, 2008; Halpern, Koren, & Szeidl, 2011; Gopinath & Neiman, 2011), expanded product scope (Goldberg et al., 2010), and quality upgrading (Amiti & Khandelwal, 2013).

Within this literature, our paper is most closely related to Amiti and Khandelwal (2013), who compute measures of industry-level quality by export market and show that a tariff reduction that leads to greater competition in the home market is associated with an increase in export quality. While also focused on quality and prices in export markets, our paper differs from Amiti and Khandelwal (2013) along several dimensions. First, while they focus on the competition effects of tariff reductions in output on quality choice, our focus is on the effect of tariff reductions on inputs. Second, while we focus on the experience of just one country, our data allow us to eliminate compositional effects by relating firm output quality responses to an exogenous shock at product-destination level. Third, our measures of the extent of trade liberalization take into account heterogeneity across firms in the magnitude of the shock and allow the effects of trade liberalization to vary across industries that differ in their scope for quality upgrading. Fourth, we document how individual firms respond to improved access to imported intermediates by shifting their export sales to markets where demand for high-quality goods is strong.

Our paper is also closely related to a literature that relates output quality to imported inputs. An important contribution in this literature is Manova and Zhang (2012), who establish many facts concerning the pricing decisions of Chinese firms. Most important for our research is their observation that firms that pay more for their imported inputs charge consistently higher prices for their exports while being more successful in export markets as measured by export revenue and the diversity of export destinations.[5] The key papers in this literature, which also include Verhoogen (2008) and Kugler and Verhoogen (2009, 2012), are more geared toward understanding in greater detail the nature of selection across firms into different activities. Our contribution to this literature is to go beyond cross-sectional comparisons among firms to carefully investigate the causal impact of trade liberalization on firm output quality holding fixed firm identities.[6]

The remainder of this paper is organized into eight sections. Section II describes the data, and section III documents the stylized facts. To explain the stylized facts, section IV presents a trade model with heterogeneous firms, featuring endogenous product quality and highlighting the difference between goods with large and small scope for quality differentiation. Section V introduces the strategy of the empirical analysis and the measurement issues. Section VI presents the main results and also indirect evidence on extensive margins of exports. Sections VII and VIII further report more statistical and conceptual robustness checks, respectively. The final section concludes.

II. Data

Our analysis of the effects of tariff reduction on export quality relies on data extracted from three sources. First, firm-product-level export and import data are obtained from China's General Administration of Customs. Second, product-level tariff data are obtained from the WTO. Finally, measures of the characteristics of Chinese firms are obtained from the National Bureau of Statistics of China (NBSC). We briefly discuss the construction of our data set but leave the details to the online appendix (see appendix A).

China's General Administration of Customs provides us with the universe of all Chinese trade transactions by importing and by exporting firm at the HS eight-digit level for the years 2001 to 2006. The initial customs data are then aggregated to the HS six-digit level for the concord of the product codes consistently over time because the concordance for Chinese HS eight-digit codes is not available to us (see details in the online appendix).[7] We excluded from our main analyses export processing firms because these firms never had to pay tariffs in the first place. As a robustness check, however, we consider a sample of export processors for a placebo analysis. Note that these prices are computed by dividing the deflated export value by physical quantities of exported products, as in De Loecker et al. (2012).[8] The Chinese import tariff data are obtained from the WTO website, available as MFN (most-favored nation) applied tariff at the HS eight-digit level for

[5] Kugler and Verhoogen (2009) find a similar pattern among Colombian manufacturing firms. They also show that among the inputs purchased by firms, those that were imported were more expensive, suggesting that they are indeed of higher quality than domestic inputs. These facts are elaborated in Kugler and Verhoogen (2012), who argue that unit values for inputs and outputs for Colombian firms suggest that the ability to produce high-quality output from high-quality inputs is a key characteristic of successful firms.

[6] In this sense, our paper is related to Verhoogen (2008), who establishes that firms that are induced to export increase their output quality. Of course, quality choice in that paper is driven by real exchange rate changes rather than by tariff reductions.

[7] The main adjustment for Chinese HS eight-digit codes occurs before and after 2002.

[8] De Loecker et al. (2012) deflate all nominal values for their analysis, and unit values are deflated by sector-specific wholesale price indexes. To compute unit values of Chinese exports, we also deflate the export value using industry-specific output deflators from Brandt, Van Biesebroeck, and Zhang (2012) (see appendix A in the online appendix for more details).

TABLE 1.—EXPORT PRICES IN 2001 AND 2006 AND PRICE CHANGES FROM 2001 TO 2006

	Export Prices		Price Changes
	2001 (1)	2006 (2)	From 2001 to 2006 (3)
Export price (HS6)			
Per firm-product, median	1.20	1.52	11.8%
Per firm-product, mean	1.40	1.80	15.7%
Export price (HS6-country)			
Per firm-product-country, median	1.13	1.51	9.14%
Per firm-product-country, mean	1.37	1.85	13.30%

Prices are in logarithm. Export prices are unit values, computed by dividing deflated export values by the physical quantity (see section II and the online Appendix for details). Price changes are presented in parentheses.

2001 to 2006 and then aggregated into the HS six-digit level.[9] In our analysis, product/variety refers to either HS6 product category or HS6-destination country combination.

Our analysis uses additional information about the characteristics of Chinese exporters for two reasons. First, we use a number of firm characteristics, such as TFP, employment, and capital intensity, as controls. Second, we want to explore how the size of the effect of import tariff reduction on export quality varies with firm characteristics. We therefore merge the firm-product-level trade data from Chinese Customs with firm-level production data, collected and maintained by the National Bureau of Statistics of China (see the detailed description of the matching process in Fan, Lai, & Li, 2012).

III. Stylized Facts

This section documents two key facts concerning the relationship between Chinese trade liberalization and Chinese export prices. We proxy for prices with unit values.[10] Because China joined the WTO in December 2001, we use the data from 2001 to represent the preliberalization period and then the data from 2006 to represent the postliberalization period. From 2001 to 2006, most products in China experienced substantial tariff reductions (see figure A.1 in the online appendix). We define a product at either HS6 or HS6-destination combination. Contrasting the changes in the measures of export prices at different levels of aggregation allows us to observe how changes in the composition of export destinations affect the average price received by exporters.

First, we examine the changes in (log) export prices by the incumbent exporting and importing firms that are present in both pre- and postliberalization periods via the levels of export prices (see table 1). We compute the median and mean (log) export price per firm-product in 2001 and in 2006 in columns 1 and 2, as well as the percentage change of prices from 2001 to 2006, in column 3.

Table 1 shows that, on average, the price levels in 2006 are always higher than the price levels in 2001. This suggests that from 2001 to 2006, those incumbent firms all raise these prices. Note that these prices are computed by deflating the export value using the domestic deflator so firms increase export prices relative to the domestic deflator after trade liberalization.

To further illustrate the shifting pattern of export prices from 2001 to 2006, we plot the distributions of the export price (in natural logarithm). In the left panel of figure 1, we include only firm-HS6 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-HS6 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 second 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:

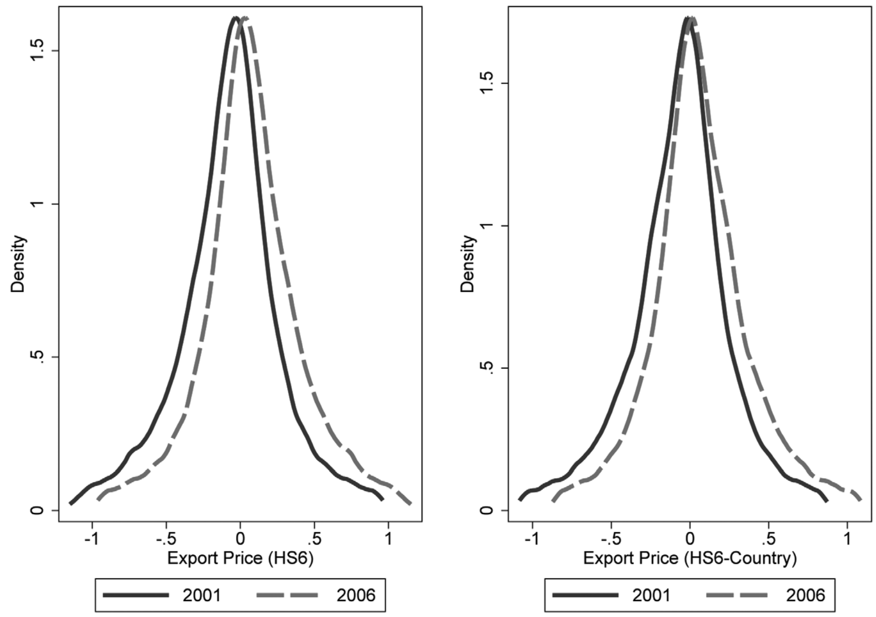
> Stylized fact 1. Firms tend to raise export prices in the post liberalization period at both product-destination level and product level.

Second, to explore whether the effect of trade liberalization on prices depends on product differentiation, we divide products into two groups: products with large scope for quality differentiation and products with small scope for quality differentiation. Adopting Rauch's (1999) product classification, 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, while the price changes in homogeneous goods are ambiguous. To further illustrate the time it takes to adjust price, we also compute the average price change year by year (see table A.1 in the online appendix) and find that the price responses clearly ascend with longer time intervals for the whole sample and for differentiated goods. Figure 2 also presents the differential effect of product differentiation on price distributions: the export prices of differentiated goods significantly increase from 2001 to 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), they even decrease after trade liberalization (see panel b). This suggests that the effect of tariff reduction on export prices depends on the scope for product differentiation. The result is summarized as the following finding:

[9] The tariff data are available at http://tariffdata.wto.org/ReportersAndProducts.aspx.

[10] This is common in the literature. According to Feenstra and Romalis, 2014, "The observed differences in export unit-values are attributed predominantly to quality."

FIGURE 1.—DISTRIBUTION OF EXPORT PRICES IN 2001 AND 2006



Prices are in logarithm and for continuing firm-HS6 product pairs (left) and firm-HS6-country pairs (right). Price distributions are drawn by regressing export prices on firm-HS6(-country) fixed effects and then plotting the residuals, as in De Loecker et al. (2012).

TABLE 2.—CHANGE IN EXPORT PRICES, 2001–2006, DIFFERENTIATED VERSUS HOMOGENEOUS PRODUCTS

	Whole Sample (1)	Differentiated Goods (2)	Homogeneous Goods (3)
Change in Export Prices (HS6)			
Per firm-product, median	11.80%	14.10%	−1.19%
Per firm-product, mean	15.72%	17.35%	3.43%
Change in export Prices (HS6-country)			
Per firm-product-country, median	9.14%	10.36%	−0.02%
Per firm-product-country, mean	13.30%	14.68%	0.90%

Prices are in logarithm. Export prices are unit values, computed by dividing deflated export values by the physical quantity (see section II and the online appendix for details). Differentiated goods and homogeneous goods are based on Rauch's (1999) product classification, representing products with a large scope for quality differentiation and products with a small scope for quality differentiation, respectively.

Stylized fact 2. In the postliberalization period, export prices in industries where the scope for quality differentiation is large tend to increase significantly while the change in export prices in industries associated with small scope for quality differentiation is nonsignificant or even ambiguous.

IV. A Model of Export Price and Quality

In this section, we provide a simple, partial equilibrium model to organize our econometric analysis. We consider the behavior of a firm that is sufficiently productive to incur fixed costs to both export a final good and import intermediate inputs. A reduction in import tariff lowers the firm's marginal costs on its existing set of imported intermediates (intensive margin) and induces the firm to expand the set of varieties imported (extensive margin). We allow the firm to choose the quality of the final good that it exports. Higher quality increases demand but comes at the cost of higher marginal costs of production. When goods are sufficiently differentiated in terms of quality, the impact of a tariff reduction on imports is an increase in quality of the export that is sufficiently large that the price of exports increases. When goods are relatively homogeneous, quality increases, but by a small enough amount that the price charged by the exporter falls.

A. Assumptions

To study how firms behave both within and across industries, we consider the following preferences:

$$U = \sum_{i}^{I} \nu_i \ln \left[\int_{\omega \in \Omega_i} q(\omega)^{\frac{\eta_i}{\sigma_i}} x(\omega)^{\frac{\sigma_i - 1}{\sigma_i}} d\omega \right]^{\frac{\sigma_i}{\sigma_i - 1}},$$

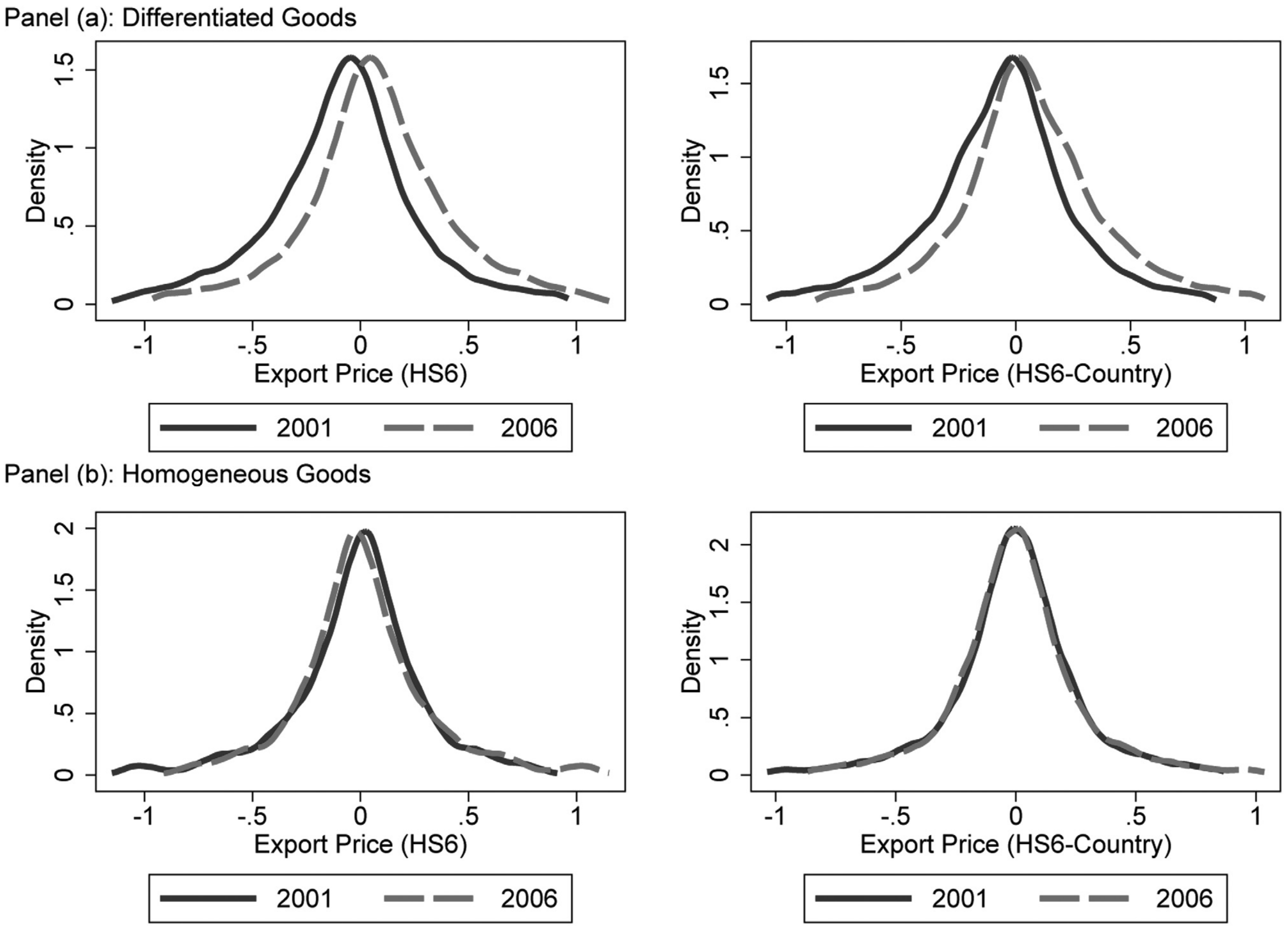
where ν_i is the share of industry i in total expenditure, $q(\omega)$ is a measure of quality of variety $\omega, x(\omega)$ is the quantity of variety ω consumed, $\sigma_i > 1$ is the elasticity of substitution across varieties of good i, $\eta_i > 0$ is a measure of the scope for quality differentiation, and Ω_i is the set of varieties available of good i. Thus, the demand for variety ω in industry i in a market with aggregate expenditure E is

$$x_i(\omega) = \nu_i E P_i^{\sigma_i - 1} q(\omega)^{\eta_i} p(\omega)^{-\sigma_i}, \tag{1}$$

where P_i is the industry-level price index that is exogenous from the point of view of individual firms.

Firms are heterogeneous in terms of their productivity $\phi(\omega)$ when producing variety ω. The final output of variety ω is created using bundles of primary factors, $L(\omega)$, and

FIGURE 2.—DISTRIBUTION OF EXPORT PRICES BY PRODUCT DIFFERENTIATION, 2001 VERSUS 2006



Prices are in logarithm and for continuing firm-HS6 product pairs (in the left panel) and firm-HS6-country pairs (in the right panel). Price distributions are drawn by regressing export prices on firm-HS6(-country) fixed effects and then plotting the residuals, as in De Loecker et al. (2012). The two graphs in the top panel refer to differentiated goods, and the two graphs in the bottom panel refer to homogeneous goods.

a composite intermediate input $M(\omega)$ that is firm specific. The production technology for a firm of productivity $\phi(\omega)$ in industry i producing a variety with quality $q(\omega)$ is given by

$$Y_i(\omega) = \chi\phi(\omega)q(\omega)^{-\alpha}L(\omega)^{1-\mu}M_i(\omega)^{\mu}, \tag{2}$$

where $\mu \in (0, 1)$, $\chi = \mu^{\mu}(1-\mu)^{1-\mu}$, and $\alpha > 0$ implies that a higher-quality variety (those with a wider range of attributes) requires more physical inputs to generate the same level of output as a lower-quality variety. The composite intermediate input is costlessly assembled from a continuum of intermediates indexed by z according to the production function

$$M_i = \Psi_i \exp\left(\int_0^{\infty} b_i(z)\ln m(z)dz\right), \tag{3}$$

where $\Psi_i = \exp\left(\int_0^{\infty} b_i(z)\ln b_i(z)dz\right)$, $m(z)$ is the quality-adjusted level of input z, and the cost shares $b_i(z)$ satisfy $\int_0^{\infty} b_i(z)dz = 1$.

Product design incurs fixed costs, and these fixed costs depend on the number of attributes that the firm chooses to build into the variety. We assume that these fixed costs are given by fq^{β_i}. The industry subscript on $\beta_i > 0$ indicates that given the nature of goods in some industries, designing products with a larger number of attributes desired by consumers differs. The higher is β_i, the more difficult it is to design products that consumers value more. Hence, a large value of β_i or a low value of η_i indicates that the scope for quality differentiation is limited.

B. *Implications*

Choosing a bundle of primary factors as the numeraire, the marginal cost of producing a variety of final output of a firm of productivity ϕ in industry i facing technology given by equations (2) and (3) is

$$C_i(q, P_i^m, \phi) = \frac{q^{\alpha}}{\phi}(P_i^m)^{\mu}, \tag{4}$$

where P_i^m is the price of the composite intermediate input. For a cost-minimizing firm, the price of the composite intermediate is given by $P_i^m = \exp\left(\int_0^{\infty} b_i(z)\ln c_m(z)dz\right)$, where $c_m(z)$ is the lowest quality-adjusted cost input available to the firm. The cost to the firm of an intermediate of type z depends on whether the intermediate was purchased from a domestic supplier or a foreign supplier.[11] If the firm purchases intermediate z locally, it pays the domestic unit price $c_m^d(z)$. If the firm imports the intermediate z, then it must first pay the international unit price of $c_m^f(z)$ and then pay tariffs of $(\tau - 1)\, c_m^f(z)$, where $\tau > 1$ is 1 plus the tariff rate. We assume that foreign producers have a comparative advantage in low z goods and domestic producers have a comparative advantage in high z goods. Formally, define $A(z) = c_m^f(z)/c_m^d(z)$. We assume that $A(0) < 1$, $A'(z) > 0$, and $\lim_{z\to\infty} A(z) > 1$. Firm optimization requires that $c_m(z) = \min(\tau c_m^f(z), c_m^d(z))$, and so we can define a cutoff intermediate z^* such that $z < z^*$ are imported and $z > z^*$ are purchased locally, where $\tau A(z^*) = 1$. It follows that the cost of a bundle of imported intermediates is given by

$$P_i^m = \exp\left(\int_0^{z^*} b_i(z) \ln\left(\tau c_m^f(z)\right) dz + \int_{z^*}^{\infty} b_i(z) \ln c_m^d(z) dz \right). \quad (5)$$

Conditional on its cost-minimizing choice on the source of intermediate inputs, the firm chooses its price, p, and its quality, q, to maximize its export profits of the firm, which are given by

$$\pi(\phi) = \max_{p,q} \left(\left(p - C_i(q, P_i^m, \phi)\right) x_i(q,p,\omega) - fq^{\beta_i} \right),$$

where demand $x_i(q,p,\omega)$ is given by equation (1) and marginal cost C_i is given by equation (4).[12] Note that we have neglected the domestic market as it is largely irrelevant to our econometric analysis.[13] To obtain an interior solution, we impose the parameter restrictions $\beta_i > \eta_i - \alpha(\sigma_i - 1) > 0$ so that the firm will choose a quality level that is strictly positive but finite. The first-order conditions allow us to solve for the optimal quality, $q(\phi, P_i^m)$, and the optimal price, $p(\phi, P_i^m)$, which are, respectively,

$$q(\phi, P_i^m) = (\Lambda_i)^{\frac{1}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}} \left(\frac{(P_i^m)^{\mu}}{\phi} \right)^{-\frac{\sigma_i - 1}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}}, \quad (6)$$

$$p(\phi, P_i^m) = \frac{\sigma_i}{\sigma_i - 1} (\Lambda_i)^{\frac{\alpha}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}} \left(\frac{(P_i^m)^{\mu}}{\phi} \right)^{\frac{\beta_i - \eta_i}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}}, \quad (7)$$

where $\Lambda_i \equiv \nu_i \left(\frac{EP_i^{\sigma - 1}}{f} \right) \left(\frac{\eta_i - \alpha(\sigma_i - 1)}{\beta_i \sigma_i} \right) \left(\frac{\sigma_i}{\sigma_i - 1} \right)^{1-\sigma_i}$ is a constant that is common to all firms in industry i. Equations (6) and (7) combined with equations (4) and (5) fully determine the variables of interest.[14]

We begin our analysis of the effect of tariffs on imported inputs by differentiating equation (5) with respect to τ to obtain

$$\frac{\tau}{P_i^m} \frac{dP_i^m}{d\tau} = \int_0^{z^*} b_i(z) dz + b_i(z^*) \times \left[\ln\left(\tau c_m^f(z^*)\right) - \ln c_m^d(z^*) \right] \tau \frac{dz^*}{d\tau} > 0, \quad (8)$$

where $dz^*/d\tau < 0$. The first term on the right-hand side is the intensive margin effect of a change in tariffs, and the second term is the extensive margin effect. Note that the extensive margin effect is second-order in τ and vanishes for small $d\tau$. Now, simple differentiation of equations (6) and (7) establishes the following two propositions.

Proposition 1. *A reduction in the tariff, τ, induces an incumbent importer or exporter to increase the quality of its exports.*

The result presented in this proposition is intuitive: a reduction in the tariff lowers the cost of intermediates P_i^m and hence lowers marginal cost C_i for any given quality level. Ceteris paribus, firms would sell a greater number of units, and so the fixed cost of designing higher-quality products is now less onerous relative to the gain in sales associated with expanding quality. Proposition 1 provides an explanation for stylized fact 1 that an existing firm tends to increase its export prices after trade liberalization.

Proposition 2. *A reduction in the tariff, τ, induces an incumbent importer or exporter to raise its export price in industries where the scope for quality differentiation is large ($\beta_i < \eta_i$) and to lower its export price in industries in which the scope for quality differentiation is small ($\beta_i > \eta_i$).*

Proposition 2 suggests that when the scope for quality differentiation is large, firms respond to a reduction in the cost of obtaining intermediate inputs by drastically increasing their quality. The increase in demand for their product due to heightened quality more than compensates for the loss of sales due to a higher price. The opposite occurs when the scope for quality differentiation is small and the benefit of expanding sales through selling more units is relatively more important. This proposition accounts for stylized fact 2.

C. Estimating Equations

Our empirical analysis will rest primarily on propositions 1 and 2, but it is worth pointing out some additional implications of the model. Logarithmically differentiating equations (6) and (7) yields the basis of our analysis:

[11] We assume perfect substitution between imported and domestic intermediates.

[12] To simplify notation, we have omitted any fixed costs associated with accessing international markets. As we focus on firms that both export and import in our empirical analyses, all firms in the data set have incurred these costs.

[13] In the data, firms produce multiple products for multiple locations, making it generally impossible to connect input use to outputs.

[14] The net revenue could be written as $\frac{1}{\sigma_i} \nu_i E P_i^{\sigma_i - 1} q(\omega)^{\eta_i - \alpha(\sigma_i - 1)} \left(\frac{\sigma_i}{\sigma_i - 1} \frac{(P_i^m)^{\mu}}{\phi} \right)^{1-\sigma_i}$, which could be compared with a standard Melitz model for a fixed quality q.

$$\Delta \ln q(\phi, P_i^m) = -\frac{\sigma_i - 1}{\beta_i - \eta_i + \alpha(\sigma_i - 1)} \times \left(\mu \Delta \ln(P_i^m) - \Delta \ln \phi\right), \quad (9)$$

$$\Delta \ln p(\phi, P_i^m) = \frac{\beta_i - \eta_i}{\beta_i - \eta_i + \alpha(\sigma_i - 1)} \times \left(\mu \Delta \ln(P_i^m) - \Delta \ln \phi\right), \quad (10)$$

where

$$\Delta \ln(P_i^m) = \sum_{z \in Z} b_i(z) \Delta \ln \tau(z) + \sum_{z \in Z'} b_i(z) \left(\ln\left[\tau'(z) c_m^f(z)\right] - \ln c_m^d(z)\right) \quad (11)$$

is the empirical analog of equation (8) that allows for tariff reductions $\Delta \ln \tau(z)$ to vary across intermediates. The first term is the intensive margin for the set of existing intermediates, Z, imported before the tariff reduction. The second term is the extensive margin for the set of newly imported intermediates, Z', and $\tau'(z)$. As the theory suggests that the extensive margin is hard to evaluate, we will ignore this second term in our baseline econometric specifications, but we also control for the extensive margin for robustness.[15]

Proposition 2 highlights the heterogeneity across industries in the impact of a tariff reduction based on the scope for quality differentiation. We will allow for this slope heterogeneity by estimating price equations for different sets of industries.

Finally, note that firm productivity $\Delta \log \phi$ enters both equations (9) and (10) so that shocks to TFP could also have an impact on qualities and prices. If these shocks to TFP were correlated with the size of the effect of tariff reductions on imported intermediates, then we could attribute to the lower cost of intermediates some of the impact that works through TFP. For this reason, we will control for the change in TFP at the firm level in some of our econometric specifications below.

V. Empirical Specifications and Measurement

In this section, we specify our econometric models and describe the measures of tariff reductions.[16]

A. Baseline Specifications

Our interest is in estimating the effect of tariff reductions, which we maintain to be exogenous to individual firms, on the price that Chinese firms charge for their exported goods and on the inferred quality of these exports. We begin with the determinants of export prices.

Price equations. As noted earlier, our theory relates export prices to import tariffs through equations (10) and (11). Motivated by these equations, we estimate the following econometric model,

$$\Delta \ln(p_{fh(c)}) = \beta_\tau \Delta Duty_f + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_f + \beta_i HHI_i + \epsilon_{fh(c)}, \quad (12)$$

where Δ denotes a change in any variable during a five-year period (i.e., between 2001 and 2006); $p_{fh(c)}$ denotes the unit value export price of HS6 product h exported by firm f (to destination country c when product is defined as HS6-country combination), and $\Delta Duty_f$ is import tariff reductions faced by firm f, which is computed by aggregating all import tariff reductions across firm f's intermediates. In addition to these key variables, we include a vector of firm controls, $\boldsymbol{\chi}_f$, and an industry-level measure of competition, the Herfindahl index, HHI_i. The vector $\boldsymbol{\chi}_f$ consists of the observables at firm level that have a potential impact on export prices to control for productivity, imported varieties, and any effect of firm scale. Specifically, these controls include estimated TFP, capital intensity, firm size (measured by total employment), average wage bill per worker, and the number of imported varieties.[17] We also control for the effect of changing competition within industry i by adding Herfindahl index, HHI_i, computed at the four-digit CIC (Chinese Industrial Classification) industry level in the initial year 2001.

We estimate the model in long differences as given by the main specification in equation (12), because adjustment to the shock of trade liberalization may be slow and there may also be issues of autocorrelation when estimating the model in levels (see Trefler, 2004). Results associated with shorter differences are qualitatively similar, however, and are reported in table A.2 in the online appendix. As the variable of interest in equation (12) is the firm-specific tariff reductions, we cluster error terms at the level of the firm to address the potential correlation of errors within each firm across different products. Thus, identification in the baseline specification is based on changes over time in the export prices within a firm for each product due to changes in tariffs.[18]

Our main focus is at the firm-product-country level, but we also consider the weighted average of export prices across export destinations. Thus, we will estimate the main specification equation (12) at various levels of aggregation in order

[15] We include both intensive margin and extensive margin in one of the alternative tariff measures, and our results are robust. See section VB for details of constructing alternative tariff measures and section VIIA for robustness results.

[16] We leave the discussion of measures of productivity to appendix C (see the online appendix) as productivity is not our focus. In this paper, our TFP measure is estimated based on the augmented Olley-Pakes method, as in Amiti and Konings (2007). The results are robust to other different approaches of estimating TFP.

[17] By adding the change in the number of imported varieties, we partially control for the extensive margin effect.

[18] Nevertheless, equation (12) could be also viewed as transformed from the level regression equation:

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

where the firm-product(-country) fixed effects, $\varphi_{fh(c)}$, and time fixed effects, φ_t, are included, but those fixed effect terms have been differenced out in the main specification, equation (12). The level regression results are not our focus but will be presented in the online appendix later (see note 38).

to infer how changes in the composition of a firm's export destinations might vary over time. In addition, we adopt a variant of equation (12) with dependent variable Δp_f representing the firm-level price change that is constructed using a Tornqvist index, as in Smeets and Warzynski (2013),

$$\Delta p_f = \sum_h \bar{s}_{fh} \Delta \ln(p_{fh}), \tag{13}$$

where $\Delta \ln(p_{fh}) \equiv \ln(p_{fht}) - \ln(p_{fh(t-5)})$, $\bar{s}_{fh} \equiv (s_{fht} + s_{fh(t-5)})/2$, t is set to be 2006, 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_f is computed as a weighted average of the growth in prices for all the individual products within firm f.

Quality equations. We follow the majority of the trade literature in defining quality as unobserved attributes of a variety that make consumers willing to purchase relatively large quantities of the variety despite relatively high prices charged for the variety. Following Khandelwal, Schott, and Wei (2013), we estimate the effective quality (quality as it enters consumer's utility) of exported product h shipped to destination country c by firm f in year t, $(q_{fhct})^{\eta}$, via the empirical demand equation, $x_{fhct} = q^{\eta}_{fhct} p^{-\sigma}_{fhct} P^{\sigma-1}_{ct} Y_{ct}$, where x_{fhct} denotes the demand for a particular firm f's export of product h in destination country c in year t and Y_{ct} is total income in country c. We take logs of the empirical demand equation and then use the residual from the following OLS regression to infer quality:

$$\ln(x_{fhct}) + \sigma \ln(p_{fhct}) = \varphi_h + \varphi_{ct} + \epsilon_{fhct}, \tag{14}$$

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 $\ln(\hat{q}_{fhct}) = \hat{\epsilon}_{fhct}$.[19] Consequently, quality-adjusted prices are the observed log prices less estimated effective quality, that is, $\ln(p_{fhct}) - \ln(\hat{q}_{fhct})$, 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. Given the value of the elasticity of substitution σ, we are able to estimate quality from equation (14). Note that this approach to measuring quality is similar to the measurement of TFP, that is, it is a residual.

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, such as Head and Ries (2001), and conclude that a reasonable range is $\sigma \in [5, 10]$. Thus, we use different values at $\sigma = 5$ and $\sigma = 10$. We also allow the elasticity of substitution to vary across industries (σ_i) using the estimates of Broda and Weinstein (2006) because their estimates are the closest to the relevant parameter in our model (see Soderbery, 2013, for recent updates on Broda and Weinstein's 2006 estimation).[20]

As a robustness check, we inferred quality by estimating σ_i using Chinese data and an IV strategy. As the estimation results based on the quality estimates using this method were highly similar to those based on Broda and Weinstein's estimates, we report the estimation details of this method and the related results in the online appendix (see appendix E.1).

B. *The Measurement of Tariff Reductions*

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 measure properly the effective tariff reductions that firms actually face. Different ways to aggregate tariffs on intermediate inputs have various pros and cons. On the one hand, one can construct firm-specific measures that use information on the exact initial bundle of intermediates imported by firms employing heterogeneous technologies. These measures provide high resolution to the firm-specific intensive margin effects of tariff reduction and are indeed suggested by our theory, but they may miss extensive margin effects, and they raise issues of endogeneity. On the other hand, one can construct industry-level measures that better capture the potential to import more intermediates but may miss much of the action on the intensive margin. Given these concerns, we consider a wide range of tariff reduction measures that collectively can paint a more comprehensive picture of the effect of trade liberalization on export upgrading. Our focus on firm-specific measures is driven by their consistency with our theory.

We consider various formulations of firm-specific measures that have different strengths and weaknesses, beginning with those that are most closely motivated by our model. According to our theoretical derivation in equation (11), we compute $\Delta \ln \tau = \sum_{h \in Z} w_h \Delta \ln \tau_h$ to capture the weighted tariff reduction across intermediates, where the weight w_h is the import share of product h in the total import value by the firm in the initial year, and the HS6 product index h is the empirical counterpart of intermediate type z in the model.[21] We also use an approximation that at product level $\Delta \ln \tau_h \approx \Delta Duty_h$ since $\tau > 1$ is 1 plus the tariff rate. This firm-specific input tariff reduction measure is theoretically justified and can reflect the changes in effective tariffs each firm faces due to its responses to trade liberalization.[22]

[19] Here $\hat{q}_{fhct} \equiv q^{\eta}_{fhct}$. In other words, the estimated quality $\hat{q}$ is corresponding to q^{η} in our model.

[20] Broda and Weinstein (2006) estimate the elasticity of substitution for disaggregated categories and report that the average and median elasticity are 7.5 and 2.8, respectively. We use their estimates aggregated to HS 2-digit level and merge with our sample.

[21] We use only the import shares as weights because we lack data on domestic intermediate use.

[22] When we use the five-year difference, this main measure is not subject to the problem of the weight change as the year 2001 is the only initial year. However, when we use other period differences, for instance, three-year difference and four-year difference, the weight will change according to different import shares in different initial years.

TABLE 3.—SUMMARY STATISTICS OF TARIFF CUTS, 2001–2006

	Average Tariff Changes	Maximum Tariff Changes
Tariff cuts for all HS products in customs data		
By HS6 product	−5.89%	−112.60%
By HS4 product	−5.43%	−112.60%
By HS2 product	−5.77%	−29.06%
Firm-specific tariff cuts in our sample		
Main measure	−5.98%	−110.88%
Alternative measure 1	−6.05%	−70.00%
Alternative measure 2	−5.94%	−70.00%
Alternative measure 3	−5.44%	−110.88%

The main measure refers to the weighted firm-specific tariff reduction measure that is consistent with our theoretical derivation. Alternative measure 1 is unweighted firm-specific tariff reduction measure; measure 2 refers to the tariff reduction measure as in Ge, Lai, and Zhu (2011) by fixing the total number of imported varieties during the whole sample period; measure 3 is the weighted firm-specific import tariff reductions of only intermediate goods.

In addition to the main measure of tariff reductions, we adopt three alternative firm-specific measures of tariff reductions to shed additional light on the mechanisms at work in the data and to assess robustness: (a) the unweighted tariff reductions, $\Delta Duty = \sum_{h \in Z} \Delta Duty_h$; (b) the arithmetic mean of tariff reductions across all imported varieties within firm both before and after the trade liberalization;[23] and (c) the weighted average tariff reductions only to goods that are clearly intermediate inputs.[24] Summary statistics of the various measures of tariff cuts are presented in table 3.

Finally, we also compute changes in industry input and output tariffs. This industry-level input-output table–based measure of tariff cuts would be more comprehensive in capturing the effect of imported inputs if firms obtain some of the foreign intermediates from other Chinese importing firms, which is possible but cannot be reflected in the current data using firm-specific measures of tariff reductions. Nevertheless, using all alternative measures of tariff cuts (including both firm-specific and industry-level measures) does not alter our main results.

VI. Main Results

In this section, we present our main results using a sample of ordinary Chinese manufacturing exporters—those that are not part of the export processing regime that allows firms to import intermediates tariff free.[25] We begin by considering a pooled sample of all industries to find the average effect of falling tariffs on firms' export prices and on their quality choices. We then consider two subsamples defined by the scope for quality differentiation and show that the response of export prices to falling tariffs differs substantially across these types of industries, as predicted by proposition 2. In all specifications, we present results at different levels of aggregation within the firm so as to shed light on compositional effects associated with tariff reductions. Finally, we present evidence at extensive margins to supplement our discussion.

A. *Import Tariffs and Export Prices*

Table 4 reports the results of our baseline regression, equation (12), with various dependent variables, including firm-product-country price change in columns 1 to 3, firm-product price change in columns 4 to 6, and firm-level price change, as defined by equation (13), in columns 7 to 9. We first discuss the results associated with long differences at the firm-product-destination level shown in columns 1 to 3. In column 1, we report the coefficient estimate of simple bivariate regression of log changes in export prices on log changes in the intensive margin measure of tariff reductions. The negative, and statistically significant, coefficient indicates that tariff reductions on imported inputs are associated with higher export prices. This result is consistent with proposition 2 where the average industry has a large scope for quality differentiation: a fall in firm-specific import tariffs of 10 percentage points increases unit value export prices at firm-product-destination level by 4.8%.

A concern with respect to the bivariate regression is that it does not control for firm characteristics such as changes in firm TFP and that the coefficient on intensive margin tariff reductions might be picking up extensive margin effects. In columns 2 and 3, we add firm controls and the Herfindahl index (HHI) at the industry level, respectively. While the individual coefficients shown in these columns need to be interpreted with care due to the fact that some of these controls are likely endogenous, the most important feature of the coefficients reported in columns 2 and 3 is that the coefficient on $\Delta Duty$ is highly robust in its magnitude and in terms of its statistical significance compared to the coefficient in column 1. Omitted variable bias does not appear to be a problem with respect to the simple regression results shown in column 1.[26] Two other observations are worthy of comment. First, firms that displayed large increases in measured TFP (second row) were observed to increase their export prices, which is consistent with some of the TFP increase being the result of producing higher quality. Second, the coefficient on Δ ln(Import Varieties) is positive but not statistically significant. The lack of statistical significance may be due to the high correlation between this variable and $\Delta Duty$.

Columns 4 to 6 report the results with the price change at firm-product level as a dependent variable. Not surprisingly,

[23] More formally, $\Delta Duty = \left(\sum_{h \in Z \cup Z'} \Delta Duty_h\right) / |Z \cup Z'|$, where Z is the set of varieties imported before the tariff reduction (intensive margin), Z' is the set of newly imported varieties after the tariff reduction (extensive margin), and $|Z \cup Z'|$ denotes the total number of imported varieties by the firm over the whole sample period. This measure includes tariff changes relevant to both the intensive margin and the extensive margin. By fixing the total number of imported varieties over the sample period, this measure isolates pure changes in tariffs rather than the changes in input bundles (Ge et al., 2011).

[24] The final goods and intermediate goods are defined by the Broad Economic Categories (BEC) classification. This measure generates smaller sample size as it loses firms that only import final goods as inputs.

[25] We show in section VIII that export processing firms are not affected by falling tariffs.

[26] Table A.3 (columns 1–3) in the online appendix presents results where only the change in ln(TFP) is included as a control. The coefficients and their standard errors in these specifications are virtually unchanged.

TABLE 4.—BASIC RESULTS: LONG-DIFFERENCE ESTIMATION, 2001–2006

	Dependent Variable								
	Δ ln(Export Price$_{fhc}$)			Δ ln(Export Price$_{fh}$)			ΔExport Price Index$_f$		
Regressor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	−0.481**	−0.484**	−0.517**	−0.659**	−0.661**	−0.704**	−0.642**	−0.632**	−0.643**
	(0.222)	(0.216)	(0.223)	(0.289)	(0.277)	(0.279)	(0.305)	(0.306)	(0.307)
Δln(TFP)		0.042***	0.042***		0.041**	0.041**		0.046***	0.045***
		(0.012)	(0.012)		(0.017)	(0.017)		(0.017)	(0.017)
Δln(Capital/Labor)		0.023	0.023		0.036	0.036		−0.00002	0.001
		(0.016)	(0.016)		(0.026)	(0.025)		(0.021)	(0.021)
Δln(Labor)		0.001	0.002		0.003	0.006		−0.003	−0.003
		(0.018)	(0.017)		(0.027)	(0.027)		(0.026)	(0.026)
Δln(Wage)		0.020	0.019		0.024	0.023		0.046*	0.046*
		(0.022)	(0.022)		(0.027)	(0.026)		(0.025)	(0.025)
Δln(Import Varieties)		0.012	0.012		0.021	0.020		0.009	0.009
		(0.013)	(0.013)		(0.015)	(0.015)		(0.018)	(0.018)
HHI			−0.442			−0.781*			−0.241
			(0.306)			(0.406)			(0.233)
Observations	14,439	14,439	14,439	7,595	7,595	7,595	2,368	2,368	2,368
R^2	.001	.003	.004	.001	.004	.005	.002	.007	.007

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. The dependent variable in specifications 1 to 3 is the (log) price change at the firm-HS6-country level, computed as the log price difference of the same firm-HS6-country triplet from 2001 to 2006. The dependent variable in specifications 4 to 6 is the (log) price change at the firm-HS6 product level; the dependent variable in specifications 7 to 9 is the price change at the firm level that is constructed using a Tornqvist index and computed as a weighted average of the growth in prices for all the individual products within firm. All regressions include a constant term. The Herfindahl index (HHI) is computed in the initial year (2001) at the four-digit CIC industry in China. All explanatory variables are firm-level variables except for HHI.

all coefficients on tariff reductions are significantly negative, confirming that tariff reductions increase export prices at various aggregation levels. The fact that the coefficient estimates tend to be larger in the more aggregated measures of export prices suggests a modest compositional effect: lower tariffs induce Chinese firms to redirect their exports to countries where higher prices can be charged. Finally, columns 7 to 9 report the results based on the firm-level price change as dependent variable, and coefficients on tariff reductions are also significantly negative.

We also conducted estimations on specifications with various period differences, such as four-, three-, and two-year differences and results remain substantially similar (see table A.2 in the online appendix). These significantly negative coefficients on tariff reductions support the prediction of proposition 2 that a tariff reduction induces an incumbent importer or exporter to raise its export price in industries where the scope for quality differentiation is large. As to the opposite prediction where the scope for quality differentiation is small, we leave to the later discussion.

B. Import Tariffs and Export Quality

The key mechanism of our model is the choice of quality. The results in table 4 support the prediction from proposition 2 that tariff reduction induces an incumbent firm to raise its export price when quality differentiation is large. However, whether the increase in unit value export prices essentially reflects the quality improvement remains to be answered. Therefore, we regress estimated product quality on tariff reductions to test proposition 1.

Table 5 reports the estimation results of equation (12) with the change in estimated effective quality as the 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, supporting the prediction of proposition 1 that a reduction in import tariff induces an incumbent importer/exporter to raise the quality of its exports. Again, all coefficients on control variables are consistent with our expectation as in the baseline regressions in table 4. Given that the primary variables, quality estimates, are generated from regressions, we also bootstrap standard errors for all specifications in table 5 and the main results remain robust (see table A.4 in the online appendix). Because of a concern that the key effect is perhaps biased by many firm-level controls, we present all the baseline regressions on prices and quality (as in tables 4 and 5) with only Δ ln(TFP) as firm control and present consistent results in table A.3 in the online appendix. We also add the two-digit CIC industry fixed effects into the baseline regressions and report similar results in table A.5 (see the online appendix).

Finally, we explored the estimation of equation (12) when the price has been quality adjusted, $\ln(p_{fhct}) - \ln(\hat{q}_{fhct})$, as the dependent variable. (To save space, we report these results in table A.6 in the online appendix). We find that reductions in import tariffs indeed induce an incumbent importer/exporter to lower its quality-adjusted prices.

C. The Role of Quality Differentiation

According to proposition 2, the effect of tariff reduction on export prices depends on the scope for quality differentiation within an industry. Firms increase export prices with tariff reductions in industries where the scope for quality differentiation is large and decrease export prices in industries where the scope for quality differentiation is small. From stylized fact 2, we know that over the period 2001 to 2006, export prices are essentially unchanged for homogeneous goods.

TABLE 5.—EFFECT OF TARIFF REDUCTIONS ON QUALITY UPGRADING

	Dependent Variable: $\Delta \ln(\hat{q}_{fhc})$					
	$\sigma = 5$		$\sigma = 10$		$\sigma = \sigma_i$	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	−3.093**	−3.125**	−6.351***	−6.623***	−3.339***	−3.304***
	(1.262)	(1.253)	(2.331)	(2.340)	(1.063)	(1.054)
Δln(TFP)		0.301***		0.496***		0.236***
		(0.063)		(0.118)		(0.056)
Δln(Capital/Labor)		0.159*		0.230		0.0948
		(0.088)		(0.160)		(0.071)
Δln(Labor)		0.263***		0.210		0.278***
		(0.092)		(0.163)		(0.091)
Δln(Wage)		0.150		0.251		0.110
		(0.111)		(0.209)		(0.090)
Δln(Import Varieties)		0.118*		0.181		0.118**
		(0.064)		(0.125)		(0.051)
HHI		−1.690		−4.386		−1.227
		(1.501)		(2.903)		(1.209)
Observations	14,439	14,439	14,439	14,439	14,439	14,439
R^2	.001	.007	.001	.006	.002	.008

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. The dependent variable is the change in the estimated (effective) quality at the firm-HS6-country level, given the value of the elasticity of substitution (σ). In specifications 1 and 2, we use $\sigma = 5$; in specifications 3 and 4, we use $\sigma = 10$; in specifications 5 and 6, we use the industry-variant σ_i based on the estimates of Broda and Weinstein (2006). All regressions include a constant term. The Herfindahl index (HHI) is computed in the initial year (2001) at the four-digit CIC industry in China. All explanatory variables are firm-level variables except for HHI.

To test whether the scope for quality differentiation indeed matters, first, we use Rauch's Product Differentiation Index (1999) to create two separate samples, one composed of differentiated goods and the other composed of homogeneous goods (see the online appendix for details). It is natural to believe that differentiated goods present greater scope for quality differentiation than do homogeneous goods. We also allow for heterogeneity in the response of export prices to tariff reductions in two ways. First, we estimate our econometric model on the two subsamples separately and compare the two coefficients on $\Delta Duty_f$. Second, we interact $\Delta Duty_f$ with a dummy variable for whether the product is in a homogeneous goods industry. In particular, we used the pooled sample to estimate

$$\Delta \ln(p_{fhc}) = \beta_\tau \Delta Duty_f + \beta_H \Delta Duty_f \times HOMOGENEOUS_h + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_f + \beta_i HHI_{i(2001)} + \epsilon_{fhc}, \quad (15)$$

where $HOMOGENEOUS_h$ is a dummy variable equal to 1 for homogeneous goods and 0 for differentiated goods. We expect a positive β_H and a negative β_τ. We also estimate the quality equation with the change in estimated effective quality $\Delta \ln(\hat{q}_{fhc})$ as the dependent variable in equation (15).

Table 6, panel A reports the estimation results of the above approaches. Columns 1 to 3 report estimation results when we regress the change in (log) price for HS6-country product on tariff reductions; columns 4 to 6 report regression results with the change in (log) estimated quality for HS6-country product as dependent variable; columns 7 to 9 report the results with the change in (log) price for HS6 product as a dependent variable. In each of the three columns, the first column uses the subsample of differentiated products and therefore presents the significantly negative coefficient on tariff reductions (see columns 1, 4, and 7) according to propositions 1 and 2; the second uses the subsample of homogeneous goods and thus yields positive but less significant coefficients on tariff reductions (see columns 2 and 8) according to proposition 2;[27] the third presents the estimation results of equation (15) or its variants with different dependent variables (see columns 3, 6, and 9). All coefficients on interaction terms are significantly positive at the (at least) 1% level. The results are consistent with our expectation and further substantiate propositions 1 and 2.[28]

Panel B of table 6 reports the estimation results of a similar equation using quality heterogeneity $QUALITY_h^{Dispersion}$ (measured by quality dispersion) instead of $HOMOGENEOUS_h$ (measured by Rauch classification), where $QUALITY_h^{Dispersion}$ is a dummy variable that is equal to 1 for goods with less dispersed quality and 0 otherwise; the dependent variable could be either price (at different aggregation levels) or estimated quality. We compute quality dispersion by using the estimated quality (at *fhc* level) to compute a quality variance for each HS6 product. Then we use the median of quality variances of all goods to distinguish products with highly dispersed quality and less dispersed quality. Again we expect a positive β_H and a negative β_τ. The result is consistent with our expectation (see columns 3, 6, and 9). The results in panel B using the subsample of goods with highly dispersed quality also show significantly negative coefficients on tariff reductions

[27] Proposition 1 does not directly differentiate between the two cases with scope for large and for small quality differentiation, respectively. However, it could be derived that when the scope for quality differentiation is small, the rise in quality would be smaller and less significant than the quality upgrading when the scope for quality differentiation is large. Therefore, we expect a nonsignificant coefficient on $\Delta Duty$ when the regressand is the change in quality for homogeneous goods. The result in column 5 is consistent with this expectation.

[28] Our results also remain robust when we use Rauch index, computed as a fractional value at industry level. The results of using Rauch index are not reported here to save space but are available on request.

TABLE 6.—EFFECT OF TARIFF REDUCTIONS AND QUALITY DIFFERENTIATION

	Dependent Variable								
	$\Delta\ln(p_{fhc})$			$\Delta\ln(\hat{q}_{fhc})$			$\Delta\ln(p_{fh})$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Differentiated Goods versus Homogeneous Goods									
ΔDuty	−0.653***	0.527	−0.695***	−4.326***	3.397*	−4.031***	−1.021***	0.832*	−1.005***
	(0.248)	(0.392)	(0.231)	(1.150)	(1.960)	(1.092)	(0.318)	(0.475)	(0.290)
ΔDuty ×*HOMOGENEOUS*			1.466***			5.974***			1.841***
			(0.316)			(1.695)			(0.379)
Observations	12,805	1,634	14,439	12,805	1,634	14,439	6,620	975	7,595
R^2	.005	.003	.005	.009	.006	.009	.007	.005	.008
B. Quality Heterogeneity Based on Dispersion of Quality									
ΔDuty	−0.901***	−0.0773	−0.707***	−4.340***	−1.260	−5.315***	−1.264***	−0.172	−1.176***
	(0.317)	(0.277)	(0.263)	(1.566)	(1.176)	(1.308)	(0.462)	(0.270)	(0.342)
ΔDuty ×$QUALITY^{Dispersion}$			0.462*			4.875***			0.934***
			(0.269)			(1.304)			(0.305)
Observations	7,207	7,232	14,439	7,207	7,232	14,439	3,785	3,810	7,595
R^2	.004	.005	.004	.009	.009	.010	.007	.005	.007
C. Quality Differentiation Based on G-M (Gollop-Monahan) Index									
ΔDuty	−0.626**	−0.045	−0.750***	−4.924***	0.978	−4.296***	−1.188***	0.247	−1.352***
	(0.263)	(0.414)	(0.247)	(1.351)	(1.735)	(1.117)	(0.398)	(0.409)	(0.336)
ΔDuty ×$QUALITY^{Diff}$			1.011***			4.175***			1.774***
			(0.313)			(1.501)			(0.380)
Observations	6,679	6,284	12,963	6,679	6,284	12,963	3,252	3,505	6,757
R^2	.004	.006	.006	.014	.006	.010	.008	.008	.010
Panels A, B, and C									
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

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. The dependent variable in specifications 1 to 3 is the (log) price change at the firm-HS6-country level; the dependent variable in specifications 4 to 6 is the change in estimated quality at the firm-HS6-country level; the dependent variable in specifications 7 to 9 is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the Herfindahl index (HHI), which is computed in the initial year (2001) at the four-digit CIC industry in China. Using ΔHHI as industry-level competition control does not alter the main results. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment). Quality estimates are based on elasticities of substitution from Broda and Weinstein (2006). The dummy variable *HOMOGENEOUS* is equal to 1 for homogeneous goods and 0 otherwise. $QUALITY^{Dispersion}$ and $QUALITY^{Diff}$ are defined as dummy variables that are equal to 1 for goods with less dispersed or less differentiated quality and 0 otherwise.

(see columns 1, 4, and 7), while those using the subsample of goods with less dispersed quality present similar patterns as homogeneous goods (see columns 2, 5, and 8). Note that the coefficient on $\Delta Duty_f$ in column 1 doubles relative to the coefficient obtained by estimating the model on the pooled sample (see table 4).

We now check the robustness of our results to using the Gollop-Monahan index to measure the scope for quality differentiation within an industry. This index measures the dissimilarity of input mixes across firms in an industry and is defined for the relevant intermediate-input sector. A higher value of the Gollop-Monahan index indicates a larger scope for product quality differentiation.[29] Panel C of table 6 reports similar estimation results of a variant of equation (15) based on G-M index using $QUALITY_h^{Diff}$ instead of $HOMOGENEOUS_h$, where $QUALITY_h^{Diff}$ is a dummy variable that is equal to 1 for goods with less differentiated quality (if that product h's G-M index value is below the median of G-M indices for all goods) and 0 otherwise.

[29] The idea is that products become more differentiated if the underlying inputs are more different, which is consistent with our mechanism that firms adjust their product quality as a response to tariff reductions through both intensive and extensive margins of their intermediates. The G-M index has been used by some previous studies, including Kugler and Verhoogen (2012), and Tang and Zhang (2012). We obtain the data of the G-M index from Kugler and Verhoogen (2012); the detailed description is contained in the online appendix.

D. Extension: Evidence at Extensive Margin

To keep our model simple, we abstracted from the decision of a firm to enter export markets. A natural extension would have fixed costs to entering foreign markets that were increasing in the quality of the good that would be sold there. In such a model, a tariff reduction that induced an upgrade in output quality would also induce an upgrade in the types of markets entered: lower tariffs on imported intermediates ought to steer exporters to markets that demand higher-quality goods. We refer to such a compositional shift as a change in the extensive margin.[30] We now show that tariff reductions on intermediate inputs induce exactly such a shift.[31]

To address shifts in the extensive margin of export markets, we distinguish three types of markets—entry, exit, and

[30] In addition to the extensive margin effect described here, there are other potential channels of quality upgrading that could supplement the quality adjustment mechanism in our model. For example, high-quality output may require high-quality inputs. This has been theoretically derived (see, e.g., Kugler & Verhoogen, 2012, among others) and empirically tested by the previous studies; for example, Manova and Zhang (2012) show that firms that charge higher export prices import more expensive inputs.

[31] As our primary focus in this paper is to address the quality upgrading at the intensive margin for existing products, we acknowledge that here we only present indirect evidence of extensive margin effect and do not test how tariff reductions affect the probabilities of firm entry or exit and product (or product-country) adding or dropping as well as their connection with quality upgrading. A more through analysis of quality upgrading along different types of extensive margins would be fruitful for future research.

TABLE 7.—PRICE LEVEL AND PRICE CHANGE FOR CONTINUING MARKETS AND MARKETS OF ENTRY VERSUS EXIT

	$\ln price_{2001}$		$\ln price_{2006}$		$\ln price_{2006} - \ln price_{2001}$	
	Continuing (1)	Exit (2)	Entry (3)	Continuing (4)	Continuing (5)	Entry versus Exit (6)
Per firm-product, median	1.16	1.10	1.36	1.29	0.11	0.14
Per firm-product, mean	1.35	1.33	1.66	1.48	0.15	0.18

If a destination market for a firm-HS6 (*fh*) combination is present in both 2001 and 2006, it is defined as the continuing type; if it appears in 2006 but not in 2001, it is characterized as the entry type; if it appears in 2001 but not in 2006, it is characterized as the exit type. Export prices are unit values, computed by dividing deflated export values by the physical quantity (see section II and the online appendix for more details).

TABLE 8.—EFFECT OF TARIFF REDUCTIONS FOR CONTINUING MARKETS AND MARKETS OF ENTRY VERSUS EXIT

	Dependent Variable: $\Delta \ln(p_{fh})$					
	All Goods		Differentiated Goods		Homogeneous Goods	
	Continuing (1)	Entry versus Exit (2)	Continuing (3)	Entry versus Exit (4)	Continuing (5)	Entry versus Exit (6)
ΔDuty	−0.562**	−0.844**	−0.818***	−1.160***	0.491	2.898**
	(0.259)	(0.405)	(0.293)	(0.427)	(0.443)	(1.352)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level competition controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,945	3,846	5,193	3,363	752	483
R^2	.004	.009	.006	.012	.007	.020

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. If a destination market for a firm-HS6 (*fh*) combination is present in both 2001 and 2006, it is defined as the continuing type; if it appears in 2006 but not in 2001, it is characterized as the entry type; if it appears in 2001 but not in 2006, it is characterized as the exit type. The dependent variable is the (log) price change at the firm-HS6 product level. The differentiated goods and homogeneous goods are based on Rauch's product classification (Rauch, 1999), representing products with a large scope for quality differentiation and products with a small scope for quality differentiation, respectively. All regressions include a constant term. Industry-level competition control refers to the Herfindahl index (HHI), which is computed in the initial year (2001) at the four-digit CIC industry in China. Using ΔHHI as the industry-level competition control does not alter the main results. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

continuing—within the same firm-product (hereafter *fh*, for short) combinations, according to their status in the preliberalization period (2001) and postliberalization period (2006). If a destination market for an *fh* combination is present in both 2001 and 2006, it is defined as a continuing type; if it appears in 2006 but not in 2001, it is characterized as an entry type; if it appears in 2001 but not in 2006, it is characterized as exit type.

Next, we compare the (log) price level and price change for different types of markets of an average *fh* combination (see table 7). We use this table to show that an upgrade in output quality would induce an upgrade in the types of markets entered. The average price for the continuing type is higher than that for the exit type (see column 1 versus column 2), and the average price for the entry type is always higher than that for the continuing type (see column 3 versus column 4). This suggests the exit of relatively lower-priced markets and the entry of relatively higher-priced markets. This also implies that the trade liberalization had the effect of shifting Chinese exports geographically from countries where demand for high-quality goods is relatively weak to markets where demand for high-quality goods is strong and thus higher export prices could be charged.

Now we focus on the price change within firm-product across different types of destination countries. We compute two measures of changes in export prices within firm-product: the price change for continuing markets, and the price change for markets of entry versus markets of exit. Within each firm-product, the price change for entry-exit is computed by the average price of each firm-product across all its newly added markets (markets of entry) in 2006 minus the average price across all its dropped markets (markets of exit) in 2001. We present the mean and median price change for continuing markets and markets of entry versus exit in columns 5 and 6 in table 7. The price changes are always greater than 0, suggesting that from 2001 to 2006, quality upgrading occurs in two channels simultaneously: one is through the continuing markets for the same firm-product; the other is via entering new markets where demand for high-quality and high-priced goods is strong and via exiting markets where demand for high-quality goods is weak.[32]

We also regress the change in price on the change in import tariff and report results in table 8.[33] Table 8 shows that for all goods and differentiated goods, the tariff reductions significantly induce firms to increase export prices in continuing markets (see columns 1 and 3) and to enter higher-priced markets and exit lower-priced markets (see columns 2 and 4). It is worth noting that the effect of tariff reduction is stronger for entry-versus-exit markets than for continuing markets. Therefore, compared with our baseline results in column 6 of table 4 for all goods, it is obvious that the

[32] We acknowledge that quality upgrading may also occur through the product-extensive margin: the average quality of exports within an HS 6-digit product category may increase also because of product selection and increased specialization at higher-priced goods within the HS6 category. As the finest product category concordance over time in China is available only up to HS 6-digit level, we do not have more disaggregated product data within HS6 to test product selection effect. A remedy is exploring product extensive margin adjustment at the HS 6-digit level within each HS4 category. We find that within each firm-HS4 combination, the mean and median (log) price changes for continuing HS6 products are 0.12 and 0.08, respectively; the mean and median (log) price change for entry-versus-exit HS6 products are 0.15 and 0.13, respectively.

[33] The data presented in table 8 define "entry" and "exit" only at *fhc* level, so we could compare entry versus exit for the same *fh* combination. This way allows the price for the same HS6 product to be compared across markets.

TABLE 9.—ALTERNATIVE FIRM-SPECIFIC TARIFF REDUCTION MEASURES

	Firm-Specific Tariff Reduction Measures							
	Measure 1		Measure 2		Measure 3		Main Measure	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Dependent Variable = $\Delta \ln(p_{fh})$								
ΔDuty	−0.658*	−0.778**	−1.131**	−1.090*	−0.619**	−0.884***	−0.704**	−1.005***
	(0.350)	(0.349)	(0.574)	(0.563)	(0.276)	(0.286)	(0.279)	(0.290)
ΔDuty × *HOMOGENEOUS*		1.880***		2.003***		1.884***		1.841***
		(0.494)		(0.552)		(0.440)		(0.379)
Industry-level competition control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,595	7,595	7,595	7,595	6,830	6,830	7,595	7,595
R^2	.005	.006	.005	.006	.003	.005	.005	.008
B. Dependent Variable = $\Delta \ln(p_{fhc})$								
ΔDuty	−0.213	−0.273	−0.808*	−0.798*	−0.581***	−0.770***	−0.517**	−0.695***
	(0.273)	(0.272)	(0.452)	(0.450)	(0.221)	(0.233)	(0.223)	(0.231)
ΔDuty × *HOMOGENEOUS*		1.480***		1.649***		1.668***		1.466***
		(0.415)		(0.479)		(0.366)		(0.316)
Industry-level competition controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,439	14,439	14,439	14,439	12,947	12,947	14,439	14,439
R^2	.003	.004	.004	.005	.004	.006	.004	.005

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. The dummy variable *HOMOGENEOUS* is equal to 1 for homogeneous goods and 0 otherwise. All regressions include a constant term. Industry-level competition control refers to the Herfindahl index (HHI), which is computed in the initial year (2001) at the four-digit CIC industry in China. Using Δ*HHI* as an industry-level competition control does not alter the main results. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment). Measure 1 (see specifications 1 and 2) is an unweighted firm-specific tariff reduction measure; measure 2 (see specifications 3 and 4) refers to the tariff reduction measure as in Ge et al. (2011) by fixing the total number of imported varieties during the full sample period; measure 3 (see specifications 5 and 6) refers to the weighted firm-specific import tariff reductions of only intermediate goods. By construction, tariff measure 3 yields fewer observations in the sample. The main measure refers to the measure used in the baseline regressions (see tables 4 and 6 for the original results).

effect of tariff reduction on price change at the firm-product level is in general a combined effect of both continuing markets and entry-versus-exit markets: that is, the magnitude of the coefficient on tariff reduction for the aggregate price change at the firm-product level is smaller than that for entry-versus-exit market while larger than that for continuing market.[34] For differentiated goods, the effect of tariff reduction is stronger than its counterparts for all goods, while for homogeneous goods, the effect of tariff reduction is weaker or even reversed (see columns 5 and 6). This corresponds to the previous proposition on quality differentiation. Again, the tariff effect is stronger in entry-versus-exit markets than that in continuing markets for both differentiated and homogeneous goods.[35]

We further decompose the continuing type into two subtypes: growing and shrinking. Given that an *fhc* or *fh* combination is present in both 2001 and 2006, if its total export value increases from 2001 to 2006, it is characterized as the growing type; if its total export value decreases, it is defined as the shrinking type. We report estimation results for growing-versus-shrinking types in table A.8 in the online appendix. The effect of tariff reductions is more significant for the growing type than for the shrinking type, and all results are consistent with propositions 1 and 2.

[34] See the coefficient on tariff reduction in column 6 in table 4 and compare with those in columns 1 and 2 in table 8.

[35] For differentiated goods, compare columns 3 and 4 in table 8 with column 7 in panel A of table 6; for homogeneous goods, compare columns 5 and 6 in table 8 with column 8 in panel A of table 6.

VII. Robustness I—Statistical

We conduct several exercises to show the statistical robustness of our results. First, we present the results based on alternative measures of tariff reductions, including firm- and industry-specific measures. In addition, we use instrumental variable (IV hereafter) estimation to address the potential issue of the endogeneity of tariff reductions and obtain similar results. Second, we confirm that our results are not biased toward big firms using the whole customs data without matching the data to the manufacturing firm survey.

A. Alternative Measures of Tariff Cuts

In Section V, we proposed a number of ways to measure the impact of tariff cuts on the cost to Chinese firms of procuring foreign-made intermediates. Our main measure, which we have used exclusively so far, has the benefit of being consistent with the intensive margin impact across firms. We now show how well the alternative tariff reduction measures predict price changes across firms.

In table 9 different columns correspond to different measures of firm-specific tariff cuts. Panel A reports the results with average prices of HS6 products across destinations, and panel B presents the results with prices of HS6-country products. In most specifications of table 9, the coefficients on the change in import tariff are significantly negative, indicating that import tariff reduction leads to higher export prices. Also, the coefficients on the interaction terms are all significantly positive, implying that the effect of import tariff reduction on export price increase is more significant for products in

TABLE 10.—INDUSTRY INPUT AND OUTPUT TARIFF CUTS

	Industry Input/Output Tariff							
	Dependent Variable: $\Delta \ln(p_{fhc})$				Dependent Variable: $\Delta \ln(p_{fh})$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \text{Duty}^{output}$	−0.377		0.508		−0.256		0.442	
	(0.343)		(0.410)		(0.313)		(0.411)	
$\Delta \text{Duty}^{input}$		−1.749***	−2.237***	−1.802***		−1.191***	−1.584***	−1.219***
		(0.419)	(0.530)	(0.417)		(0.450)	(0.567)	(0.447)
$\Delta \text{Duty}^{input} \times HOMOGENEOUS$				1.583***				1.567**
				(0.481)				(0.797)
Industry-level competition control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,439	14,439	14,439	14,439	7,595	7,595	7,595	7,595
R^2	.003	.005	.005	.006	.004	.005	.005	.006

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the HS6 product level in parentheses, because we use the concordance between HS6 products and the Chinese input-output sector to compute industry input and output tariffs. The dummy variable *HOMOGENEOUS* is equal to 1 for homogeneous goods and 0 otherwise. All regressions include a constant term. Industry-level competition control refers to the Herfindahl index (HHI), which is computed in the initial year (2001) at the four-digit CIC industry in China. Using ΔHHI as industry-level competition control does not alter the main results. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

industries where the scope for quality differentiation is large. When measure 1 (unweighted tariff reductions in columns 1 and 2) is compared with the main measure (weighted tariff reductions as in tables 4 and 6, now in columns 7 and 8 in table 9), the effects of tariff reductions are far stronger for measures that allow different input tariffs to receive different weights. This indicates that allowing for more important inputs to receive a higher weight is important: large tariff reductions have a bigger impact the more that intermediate input is used in production. By construction, measure 2 (tariff cuts measured based on the entire set of imported inputs from 2001 as well as 2006) captures both the intensive and extensive margin impact on Chinese importers. Because our main measure and measure 1 capture only the intensive margin, we would expect the coefficient estimate based on measure 2 to be substantially larger in these specifications. This is indeed the case, as the coefficients in columns 3 and 4 are substantially larger in absolute value than those in the baseline regressions, as shown by columns 7 and 8.[36] Finally, limiting the set of imported intermediates to those clearly classified as such has little impact on the coefficient estimates (see columns 5 and 6).

One might worry that the reduction in import tariffs on intermediate inputs might be correlated with cuts in tariffs on firms' outputs and that our results might be spuriously picking up the competition effects that are the focus of Amiti and Khandelwal (2013). Further, one might wonder as to whether a broader measure of tariff cuts on intermediate inputs that included all likely relevant tariffs delivers similar results. We now address these potential concerns by including output tariffs per exported product and input tariffs constructed using input-output matrixes.

Table 10 reports the results based on industry input and output tariffs. Columns 1 to 4 present the results using the price change for HS6-country product as the dependent variable, and columns 5 to 8 report the results with the price change for HS6 product. When we regress the price change on the industry output tariff change (see columns 1 and 5), the coefficients on output tariff are negative yet insignificant. When we regress the price change on industry input tariffs using the broadest measure of input tariff relevance (see columns 2 and 6), the coefficients on input tariff are significantly negative and very large in terms of their magnitude, implying that lower input tariffs can raise export prices through the quality effect that is the focus of our paper. The large magnitude of the coefficient suggests that the extensive margin is important, as is the potential impact of tariff cuts on the price of competing domestic inputs. When we include both input and output tariffs as explanatory variables, the effect of the input tariff, the key variable of interest, is still significantly negative (see columns 3 and 7), which further confirms that input tariff reductions raise export prices and also dispels the concerns about the competition effect.[37] Finally, we estimate equation (15) 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 Proposition 2 that prices significantly increase with tariff reductions in industries with a large scope for quality differentiation, while in industries with a small scope for quality differentiation, the price increase is significantly smaller. Thus, adopting industry-level tariffs and controlling for competition effect through output tariffs do not alter our results.[38]

Using industry-level input tariffs to some extent alleviates the concern of the potential endogeneity of tariff reductions

[36] The only other difference between the main measure and measure 1 is that the former is weighted while the latter is unweighted.

[37] Industry-level output tariffs reflect a competition effect. If we add industry-level output tariffs to our main specification with firm-level import tariff reductions, similar results are obtained and would be available on request.

[38] To provide more evidence on the relationship between tariffs and export prices, we also conduct the baseline regression in levels (see note 18) with industry input-output tariffs in table A.9 in the online appendix. We present the results of level regressions with industry- instead of firm-specific tariffs because we do not have theoretical justification of firm-specific tariffs in levels. Our theoretically derived firm-specific measures refer to tariff reductions at the firm level. The results of level regressions show that higher export prices are also associated with lower input tariffs.

TABLE 11.—LONG-DIFFERENCE ESTIMATION BASED ON FULL CUSTOMS DATA

	(1)	(2)	(3)	(4)	(5)
	Main Measure	M1	M2	M3	Industry Measure
A. Dependent Variable = $\Delta\ln(p_{fhc})$					
ΔDuty	−0.477***	−0.161	−0.691**	−0.427***	−0.925***
	(0.156)	(0.191)	(0.295)	(0.155)	(0.338)
ΔDuty × *HOMOGENEOUS*	1.166***	1.572***	1.949***	1.080***	1.724***
	(0.287)	(0.274)	(0.297)	(0.301)	(0.313)
Observations	48,095	48,095	48,095	44,232	48,095
R^2	.001	.001	.002	.001	.002
B. Dependent Variable = $\Delta\ln(p_{fh})$					
ΔDuty	−0.321	−0.546**	−0.906**	−0.407*	−0.784**
	(0.211)	(0.236)	(0.386)	(0.225)	(0.318)
ΔDuty × *HOMOGENEOUS*	1.317***	1.524***	1.714***	1.392***	1.565***
	(0.256)	(0.286)	(0.311)	(0.293)	(0.302)
Observations	31,245	31,245	31,245	29,229	31,245
R^2	.001	.001	.001	.001	.001

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level for firm-specific tariff reductions (see columns 1 to 4) and at the HS6 product level for industry input tariff reductions (see column 5) in parentheses, because we use the concordance between HS6 products and the Chinese input-output sector to compute industry input tariffs. The dummy variable *HOMOGENEOUS* is equal to 1 for homogeneous goods and 0 otherwise. All regressions include a constant term. Columns 1 to 4 refer to firm-specific measures of tariff reductions, and column 5 corresponds to industry input tariff-reduction measure, $\Delta Duty^{input}$. Column 1 adopts our main tariff-reduction measure as in the baseline regressions (see tables 4 and 6 for the original results). Columns 2 to 4 employ the three alternative measures of tariff reductions (for short, M1, M2, and M3), as described in order in section VB. Measure 1 (M1) in column 2 is an unweighted firm-specific tariff reduction measure; measure 2 (M2) in column 3 refers to the tariff reduction measure as in Ge et al. (2011) by fixing the total number of imported varieties during the whole sample period; measure 3 (M3) in column 4 is the weighted firm-specific import tariff reductions of only intermediate goods. By construction, tariff measure 3 yields fewer observations in the sample.

but cannot completely eliminate the concern. To fully address this endogeneity issue, we also conduct the IV estimation by employing past levels of tariffs as instruments. The results are similar to our main results. To save space, we present IV estimation results in the online appendix (see the details in appendix E.4).

B. *Large Sample Test Using Whole Customs Data*

So far our empirical results are based on the merged data built on the NBSC manufacturing survey database and the Customs database. However, the NBSC manufacturing survey includes only above-scale firms, which may lead to sample selection bias. Therefore, to further verify that our results are not biased toward big firms, we replicate baseline regressions with both firm-specific tariff reductions and industry input tariff reductions in table 11. The results show that 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 the scope for quality differentiation is large but may decrease prices when the scope for quality differentiation is small. We also plot the price distribution based on the full customs data in figure 3 to confirm the different patterns of price change by product differentiation. As in figure 2, which is based on the merged data in stylized facts, the price distribution apparently shifts to the right for differentiated goods, while this price-shifting pattern is nonsignificant or even reversed for homogeneous goods.

VIII. Robustness II—Alternative Explanations

We now assess the robustness of our interpretation of the results relative to alternate explanations. First, we show that our results do not seem to be due to firms' adjustment of markups in the wake of the tariff reduction. Second, we provide more discussion that our main results do not appear to be driven by other potential mechanisms. In addition, we use processing exporters as a comparison group to show that our quality upgrading mechanism is specific to ordinary exporters because processing trade firms do not pay tariffs.

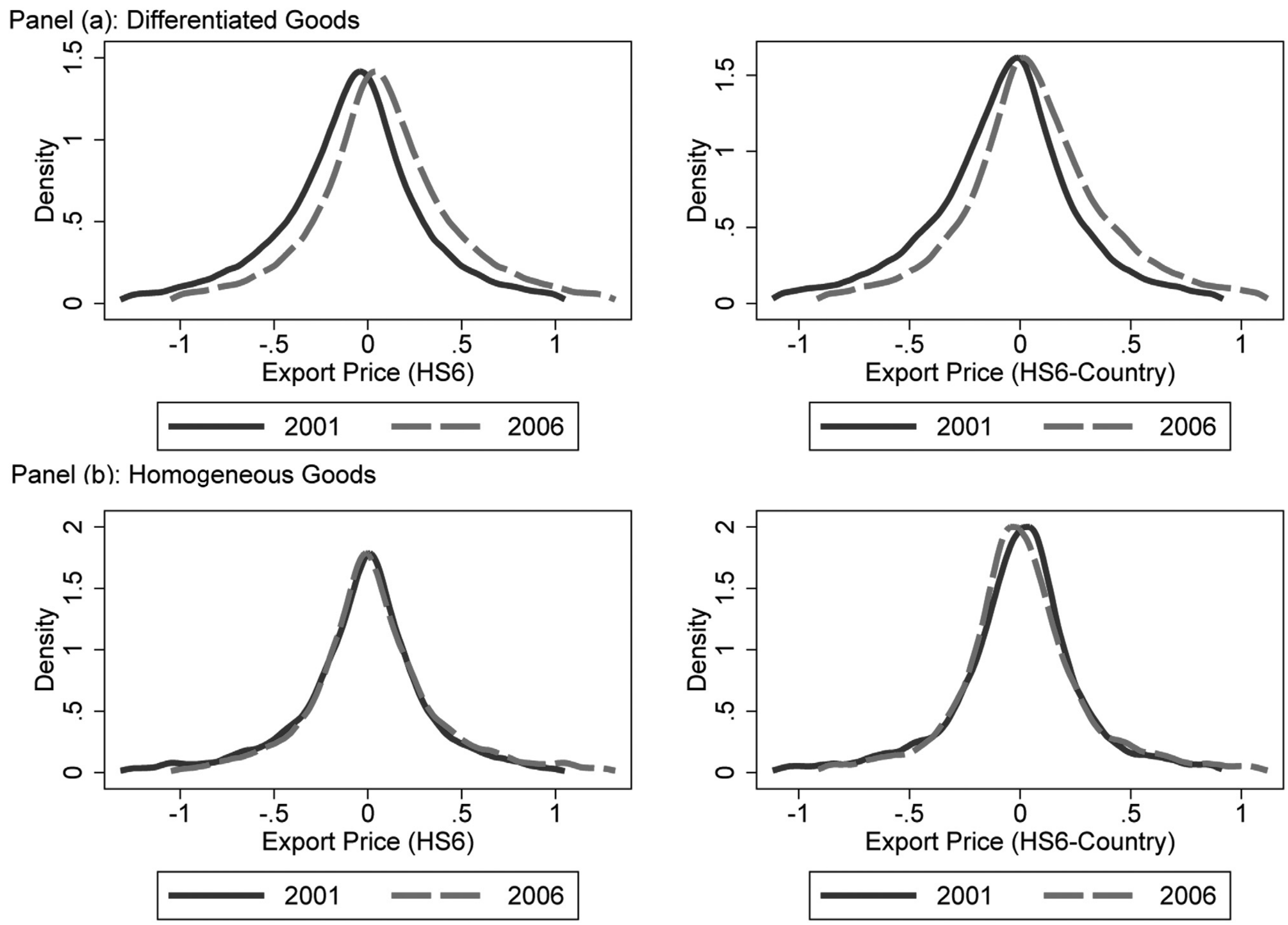
A. *Markup Adjustments*

A natural concern is whether our results reflect heterogeneous responses across firms in adjusting their markups that happen to be correlated with the size of the tariff reductions that they experience (see Halpern & Koren, 2007). We address this issue by including the change in market share directly in our estimation to control for the change in markup. This controls for variation in markups because a firm's markups tend to increase in a firm's market share (see proposition 1 in Amiti, Itskhoki & Konings 2014) and their empirical analysis as support for this monotonic relationship).[39]

In specifications 1 and 2 in panel A of table 12, we rerun the baseline regressions for $\Delta\ln p_{fhc}$ (as in column 3 in table 4) but include the change in a firm's market share as a control variable for all goods and differentiated goods, respectively. After controlling for the change in market share, the coefficients on tariff reductions are still significantly negative. This alleviates the concern that our results reflect markup variation

[39] Consider the pricing behavior of a firm i that is not measure 0 and facing a CES demand system. The profit function for this firm is given by $(p_i - c_i)\frac{Ep_i^{-\sigma}q_i^{\eta}}{\sum_j p_j^{1-\sigma}q_j^{\eta}}$, where E is expenditure on the good category and quality q_i has been included for completeness. Using a first-order condition and taking logarithms, we have $\ln p_i = \ln c_i + \ln\left(1+\frac{1}{(\sigma-1)(1-s_i)}\right)$, where $s_i \equiv \frac{p_i^{1-\sigma}q_i^{\eta}}{\sum_j p_j^{1-\sigma}q_j^{\eta}}$ is the market share of firm i. Taking the difference of log price and using a first-order Taylor approximation of the log markup, we can derive that $\Delta\ln p_i = \Delta\ln c_i + \frac{1}{\sigma-1}\Delta s_i$.

FIGURE 3.—DISTRIBUTION OF EXPORT PRICES BASED ON FULL CUSTOMS DATA, 2001 VERSUS 2006



Prices are in logarithm and for continuing firm-HS6 product pairs (left) and firm-HS6-country pairs (right). Price distributions are drawn by regressing export prices on firm-HS6(-country) fixed effects and then plotting the residuals, as in De Loecker et al. (2012). The top two graphs refer to the differentiated goods; the bottom two graphs refer to homogeneous goods.

rather than quality adjustments. Also note that this effect is more prominent for differentiated goods (see column 2 versus column 1). To address the potential endogeneity of the market share change, we also use instrumental variable estimations to show the robustness of our results in table 12: we employ initial tariff levels in 2001 (see columns 3 and 4) and tariff changes (see columns 5 and 6) facing all other firms in the same two-digit CIC industry to instrument the market share change for each individual firm, where columns 3 and 5 are for all goods and columns 4 and 6 are for differentiated goods. The diagnostic statistics in all specifications support the validity of the instruments and fit the first stage well. Again, instrumenting for market share changes does not alter the significant effect of tariff reductions on price increase.

We then conduct another exercise by moving the change in market share to the left-hand-side of the regression equation, that is, we subtract the market share change from the price change and call this new dependent variable the markup corrected price.[40] Panel B of table 12 reports the regression results for markup corrected prices. Columns 1, 3, and 5 report results for all goods, and columns 2, 4, and 6 present results for differentiated goods. The coefficients on tariff reductions on markup corrected prices are negative in all specifications and keep the statistical significance in most specifications.

Furthermore, Amiti et al. (2014) show that in markets where the firm has a small market share, it is hard for the firm to adjust its markup in those markets. Thus, we rank all firms based on their market share in each destination market and run regressions for firms with small market shares (see appendix E.5 in the online appendix for details). All of these exercises suggest that our results are not primarily driven by changes in markups.

B. *More Discussion*

There may exist other mechanisms through which tariff changes could potentially affect quality choice. These include reduced uncertainty about the ability to export to high-income markets and currency appreciation. We conduct the sensitivity tests for policy uncertainty and currency appreciation; results are presented in the online appendix (see appendix

[40] Following note 39, the markup corrected price is given by $\Delta \ln p_i - \frac{1}{\sigma-1}\Delta s_i$.

TABLE 12.—RESULTS WITH CONTROLLING FOR MARKET SHARE CHANGES

A. Results with Controlling for Market Share Changes	No Instrument		Instrumented by $Duty_{2001}$		Instrumented by $\Delta Duty$	
Dependent variable = $\Delta \ln p_{fhc}$	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	−0.503**	−0.631**	−0.432*	−0.520*	−0.520**	−0.658**
	(0.223)	(0.248)	(0.245)	(0.274)	(0.237)	(0.275)
ΔMarket share	0.110***	0.117***	0.682	0.691*	−0.030	−0.024
	(0.027)	(0.030)	(0.449)	(0.396)	(0.551)	(0.510)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level competition control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,439	12,805	14,439	12,805	14,439	12,805
R^2	.006	.006	.005	.008	.003	.004
Kleibergen-Paap rk LM $\chi^2(1)$ statistic			22.493*	28.638*	11.155*	13.112*
Weak instrument (F-statistic)			24.331*	32.032*	11.589*	14.048*

B. Results for Markup Corrected Prices	$\sigma = 5$		$\sigma = 10$		$\sigma = \sigma_i$	
Dependent variable = $\Delta \ln p_{fhc}$	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	−0.486**	−0.605**	−0.503**	−0.632**	−0.321	−0.413*
	(0.225)	(0.249)	(0.223)	(0.248)	(0.225)	(0.247)
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level competition control	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14,439	12,805	14,439	12,805	14,439	12,805
R^2	.004	.004	.004	.005	.003	.003

Significant at ***1%, **5%, and *10%. Robust standard errors are corrected for clustering at the firm level in parentheses. R^2 for columns 3 to 6 refers to the shea partial R^2 in the first stage. All regressions include a constant term, firm-level controls, and industry-level competition controls. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment). Industry-level competition control refers to the Herfindahl index (HHI), which is computed in the initial year (2001) at the four-digit CIC industry in China. Using ΔHHI as an industry-level competition control does not alter the main results.

E.6). To remove the potential for the policy uncertainty mechanism to drive our results, we remove the United States from our sample because Pierce and Schott (2013) have shown that the majority of the uncertainty of Chinese exports stems from the sudden loss of MFN status in Chinese trade relations with the United States. The results after removing the U.S. data are similar to our main results. One may be also concerned that the price increase is partially due to the appreciation of the Renminbi (RMB). To test the sensitivity of our results to RMB appreciation, we use the data before the appreciation and confirm that export prices indeed increase even without currency appreciation.[41]

Moreover, we use processing exporters as a comparison group to show that processing firms, which never paid tariffs on inputs, do not significantly increase export prices. We report the results of processing exporters in the online appendix (see appendix E.7). We find no evidence that pure processing exporters increase their export prices in response to tariff reductions. We also note that it is possible that some firms in our sample may switch their trade regimes between ordinary trade, processing trade, and hybrid trade. Nevertheless, we show the robustness of our main results to the changes in the margins of trade regimes (also see the online appendix).

[41] As the RMB appreciated in late 2005, we dropped data for 2005 and 2006, and conduct the long-difference estimation for the period between 2001 and 2004 (see appendix E.6 in the online appendix for more detail).

IX. Conclusion

In this paper, we uncover patterns of price and quantity adjustments in the wake of trade liberalization that strongly suggest that access to imported intermediate inputs can substantially increase the ability of firms to deliver high-quality goods to foreign markets. We first uncover interesting price adjustments across firms that can clearly be documented in a series of figures. We then devise an econometric model from a simple analytical framework of quality choice and access to imported intermediates. Estimating this model on Chinese data in the post-WTO accession period, we find strong and robust evidence that firms in industries where quality heterogeneity is substantial that experienced the largest tariff reductions on their imported inputs increase the price and quality of their outputs.

Our study has imposed relatively little structure on the data. While this allows us to take a diverse set of cuts of the data to establish the existence and robustness of our results, it does come at the cost of limiting a complete assessment of magnitudes that a more structural approach would allow. Such a structural approach would incorporate a number of important elements. First, formally modeling the decisions to export would allow us to more thoroughly trace out the complementarities between imported intermediates and exports. Second, while we argued that our results are not primarily driven by markup adjustments, a more structural approach would allow the actual contributions of our mechanism and markup adjustments to be quantified. Finally, a more structural model would allow the relative contributions of the extensive and intensive margins to be separately identified. We hope that our paper provides the impetus for an expansion in research along these lines.

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