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Abstract

This paper presents theory and evidence from highly disaggregated Chinese data that tariff reductions induce a country's producers to upgrade the quality of the goods that they export. The paper first documents two stylized facts regarding the effect of trade liberalization on export prices and its relation with product differentiation. Next, the paper extends Melitz's (2003) model of trade with heterogeneous firms by introducing endogenous quality choice. The model predicts that a reduction in the import tariff induces an incumbent importer/exporter to increase the quality of its exports and to raise its export price in industries where the scope for quality differentiation is large while to lower its export price in industries where the scope for quality differentiation is small. The predictions are consistent with the stylized facts based on Chinese data and robust to various estimation specifications.

JEL: F12, F14

Keywords: trade liberalization, tariff, quality, export price, quality upgrading

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1 Introduction

Rapid trade liberalization has transformed the economies of many developing countries. As these countries have scaled back tariffs, their firms have gained access to cheaper and higher quality intermediate inputs from abroad. Greater access to foreign intermediate inputs has been associated with higher firm-level productivity (Pavcnik, 2002; Amiti and Konings, 2007, among others),[1] and other firm-level adjustments in domestic product scope, export value, and export scope, for instance, Goldberg et al. (2010).

In this paper, we present theory and evidence from highly disaggregated Chinese data that tariff reductions also induce a country's producers to upgrade the quality of the goods that they export.[2] Such a link between trade liberalization and export quality is important because the production of high-quality goods is often viewed as a pre-condition for export success and for economic development (Amiti and Khandelwal, 2013). As shown by Schott (2004), international specialization is largely across levels of quality within industry rather than across industries, which suggests that development is in part about the upgrading of the quality of an existing set of goods. Our results demonstrate that tariffs can hold back quality upgrading and thus development if they raise the cost of importing high quality inputs.

We begin our analyses by documenting two stylized facts regarding the relationship between the arguably exogenous tariff reductions imposed on China by WTO accession and export prices for ordinary (non-processing) Chinese exporters. First, as the tariffs paid by a firm on imported inputs fall, the firm raises its export prices at different aggregation levels. Second, this effect is limited to only differentiated goods, and is even reversed for homogeneous goods.

We explain these facts and extend Melitz (2003) by introducing endogenous product quality. Focusing on the behavior of firms that both import and export, we analyze the impact on a firm's export prices and product quality of a reduction in intermediate input tariffs. In the model, a reduction in import tariff induces firms to choose higher output quality and to increase export prices in industries where the scope for quality differentiation is large, but in industries where the scope for quality differentiation is small, a reduction in import tariff induces firms to lower export prices.

We then test the model's predictions using a panel data for Chinese firms over the period 2001-2006. The unilateral trade liberalization imposed on China as a condition of accession to the World Trade Organization (WTO) provides a source of exogeneous variation that allows us to quantify the impact of tariff reduction on firm export prices.[3] Another advantage of our firm-level data combined

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

[2] De Loecker et al. (2012) use Indian data to make related points about the effect of trade liberalization on prices and markup.

[3] As is well known, China has long enjoyed MFN treatment by major trading partners prior to joining the WTO. We acknowledge that foreign importers may have been induced to form longer term relationships with Chinese producers

with product-level Chinese customs data is that it allows us to create very precise firm-level measures of import tariff reductions. These firm-level tariff reduction measures allow us to capture the true extent of within industry heterogeneity in trade liberalization. To confirm the robustness of our results, we also employ the conventional measures of industry input/output tariffs and show that they also substantiate the predictions of our model. We focus primarily on long differences at the firm-product-country level to eliminate many sources of time invariant heterogeneity and to address concerns of the endogeneity of firm-level import behavior by using instrumental variable estimation.

Our empirical estimates confirm the main predictions of our model. First, firms that face larger reductions in the tariffs imposed on their imported inputs see their export prices rise when the exported good is in an industry where the scope for quality differentiation is large but not when the exported good is in an industry where the scope for quality differentiation is small. This result does not appear in a placebo sample of export processing firms that were never subjected to tariffs. The result does appear, largely unchanged, when looking at various time spans over which there is less exchange rate variation. Finally, the results appear with or without the inclusion of a large battery of time varying firm and industry controls.

The key value-added of this paper is to provide compelling analysis that trade liberalization induces firms to upgrade their export quality. The comparison of testing both the cases associated with large and small scope for quality differentiation provides evidence to support the mechanism of *quality adjustment*. A key strength of the empirical analysis is that it demonstrates that export prices rise where they should be rising: in goods with greater scope for quality upgrading, i.e., goods in an industry with larger scope for quality differentiation. Essentially, homogeneous goods and goods in an industry with small scope for quality differentiation are a placebo: tariff reductions do not lead to higher export prices where they should not.

This paper contributes to several branches of the literature on trade liberalization. First, this paper is related to the literature examining the effect of imported inputs on productivity and growth, such as Kasahara and Rodrigue (2008) and Halpern et al. (2011). Second, this paper joins the literature exploring the effect of trade liberalization on productivity, for example, Trefler (2004) for Canada, Amiti and Konings (2007) for Indonesia, Topalova and Khandelwal (2011) for India, Pavcnik (2002) and Tybout et al. (1991) for Chile, among others. A key strength of our paper is in the level of disaggregation afforded by the data and by the estimation strategy. Our analysis holds constant the firm-product-country of destination, thereby eliminating many possible sources of spurious variation. Our focus on export prices and qualities also goes far in identifying quality variation separately from variation in production efficiency.

This paper also complements the large quality-and-trade literature in confirming the prevalence of product quality heterogeneity at the firm level and the mechanism of quality in the presence of trade

after accession.

liberalization. Our finding of a positive relationship between firm productivity and export prices is consistent with the findings of the literature on product quality.[4] What distinguishes our paper from the literature, however, is that we emphasize that the impacts of trade liberalization on optimal prices act through the optimal adjustment of product quality. Lastly, this paper complements the empirical literature by affirming the effects of imported intermediate inputs on firms' attributes such as domestic product scope, export value, and export scope, for example, Goldberg et al. (2010) find that the use of imported inputs increases product scope for Indian firms.

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

2 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 is obtained from China's General Administration of Customs. Second, product-level tariff data is obtained from the World Trade Organization. Finally, measures of the characteristics of Chinese firms is obtained from the National Bureau of Statistics of China (NBSC). We briefly discuss the construction of our dataset in turn as follows but leave the details to Appendix A.1.

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 8-digit level for the years 2001-2006. Each trade transaction includes import and export values, quantities, products, source and destination countries, custom's regime (e.g. "Processing and Assembling"and "Processing with Imported Materials"), type of enterprise (e.g. state owned, domestic private firms, foreign invested, and joint ventures), and contact information for the firm (e.g., company name, telephone, zip code, contact person). We selected a subsample of firms from this dataset that met several requirements. First, as our interest is the effect of tariff reduction on export quality, 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. Second, we also exclude all intermediary firms from the customs data, following the similar method as in Ahn et al. (2011) and Tang and Zhang (2012). The trade data is then aggregated to firm-product-country-year. We have aggregated the data to the HS 6-digit level so as to be able to concord it consistently over

[4]For example, Verhoogen (2008), Kugler and Verhoogen (2012), Hallak (2010), Johnson (2012), Gervais (2013), Manova and Zhang (2012a), among others.

time because China changed HS 8-digit codes in 2002, and the concordance between the old and new HS 8-digit codes (before and after 2002) is not available. To ensure the consistency of the product categorization over time (2001-2006), we adopt HS 6-digit codes maintained by the World Customs Organization (WCO) and use the conversion table from the UN Comtrade to convert the HS 2002 codes into the HS 1996 codes. For the export price, we compute unit values by dividing deflated export values by physical quantities.[5]

The Chinese import tariff data are obtained from the WTO website, available as MFN (most-favored nation) applied tariff at the HS 8-digit level and our sample period is 2001-2006.[6] We are forced to aggregate this data to the HS 6-digit level, however, and the average tariff is then computed at HS6 level by using each HS8 tariff line within the same HS6 code. Our empirical analysis for product/variety therefore refers to either HS6 product category or HS6-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 will 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 (NBSC). This database covers all state-owned enterprises (SOEs), and non-state-owned enterprises with annual sales of at least 5 million RMB (Chinese currency). The NBSC database contains detailed firm-level information of manufacturing enterprises in China, such as employment, capital stock, gross output, value added, firm identification (e.g., company name, telephone number, zip code, contact person, etc.), and complete information on the three major accounting statements (i.e., balance sheets, profit & loss accounts, and cash flow statements).

We use the contact information of manufacturing firms to match the firm-product-level trade data from the Chinese Customs Database to the NBSC Database.[7] Compared with all the exporting and importing firms under the ordinary trade regime reported by the Customs Database, the matching rate of our sample (in terms of the number of firms) covers 45.3% of exporters and 40.2% of importers, corresponding to 52.4% of total export value and 42% of total import value reported by the Customs Database. Compared with the manufacturing exporting firms in the NBSC Database, the matching rate of our sample (in terms of the number of firms) varies from 54% to 63% between 2001 and 2006, which covers more than 60% of total value of firm exports in the manufacturing sector reported by the NBSC Database. We cannot compare our sample with the NBSC Database regarding the number of importers and total import value because the NBSC Database does not contain any information on

[5]We deflate the export value using output deflators and the import value using input deflators from Brandt et al. (2012). The deflator is at 4-digit CIC (Chinese industrial classification) industry level. (see appendix A.1 for more details)

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

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

firms' imports. To explore whether the reduction in the sample due to the merging of the databases is an issue, we compare the relationship between export prices and quality and import tariffs in the full sample of the Customs Database to the smaller merged sample and find no significant differences.

3 Stylized Facts

This section documents two stylized facts about the relationship between trade liberalization and export prices and how this relationship depends on product differentiation based on Chinese data. As China joined the WTO in December of 2001, we use the data from 2001 to represent the pre-liberalization period, and then use the data from 2006 to represent the post-liberalization period. We define product at either HS6 level or HS6-destination country level. We adopt two aggregation levels for product definition because in future econometrics specifications we will show that compositional effect, that is the redirection of exports to countries where higher prices can be charged, does occur, but that the size of compositional shifts is relatively modest.

First, we examine the changes in (log) export prices by the incumbent exporting/importing firms that are present in both pre- and post-liberalization periods via the levels of export prices in both 2001 and 2006 (see Table 1). We divide firms into two groups, namely, high-productivity firms and low-productivity firms, according to whether their labor productivity (value added per worker) is above or below the median in the pooled sample in 2001.[8] Within each group, we compute the median and mean (log) export price per product per firm in 2001 and in 2006.

Table 1: Export Prices in 2001 and 2006

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

Table 1 shows that on average, within each group of firms (i.e., either more productive or less productive firms), 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 unit value export prices. Note that unit value export prices are computed by deflated export value, and therefore, it implies that in general firms increase export prices relative to domestic deflator after trade liberalization. Also, in the same year, the price levels of high-productivity firms are always higher than those of low-productivity firms. To further illustrate the shifting pattern of export prices from 2001 to 2006, we plot the distributions of

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

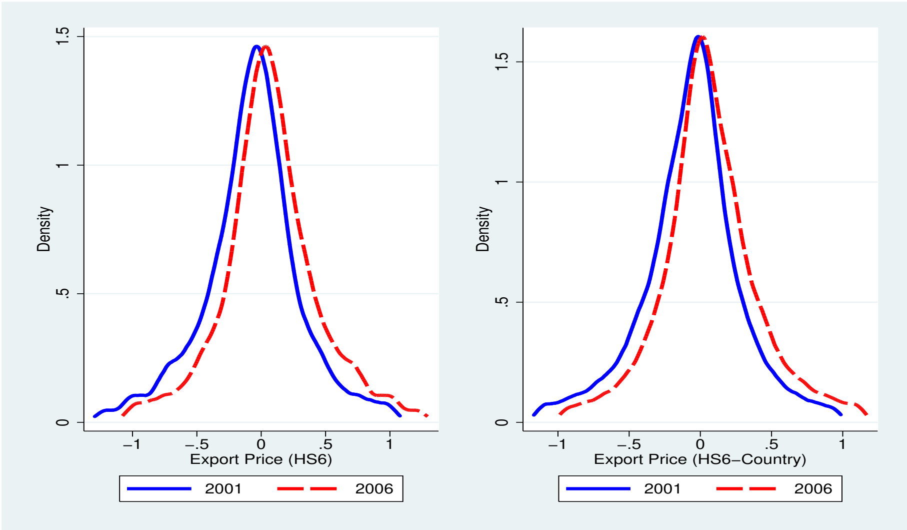

Figure 1: Distribution of Export Prices in 2001 and 2006

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 2nd percentiles. The distributions of export prices for both HS6 product and HS6-country move to the right in 2006. Thus, we summarize the first stylized fact as follows:

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

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

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

Notes: Change in price is in percentage term.

Second, to explore whether the effect of trade liberalization on prices depends on product differentiation, we divide products into two groups: products with large scope for quality differentiation and products with small scope for quality differentiation. Adopting Rauch's product classification

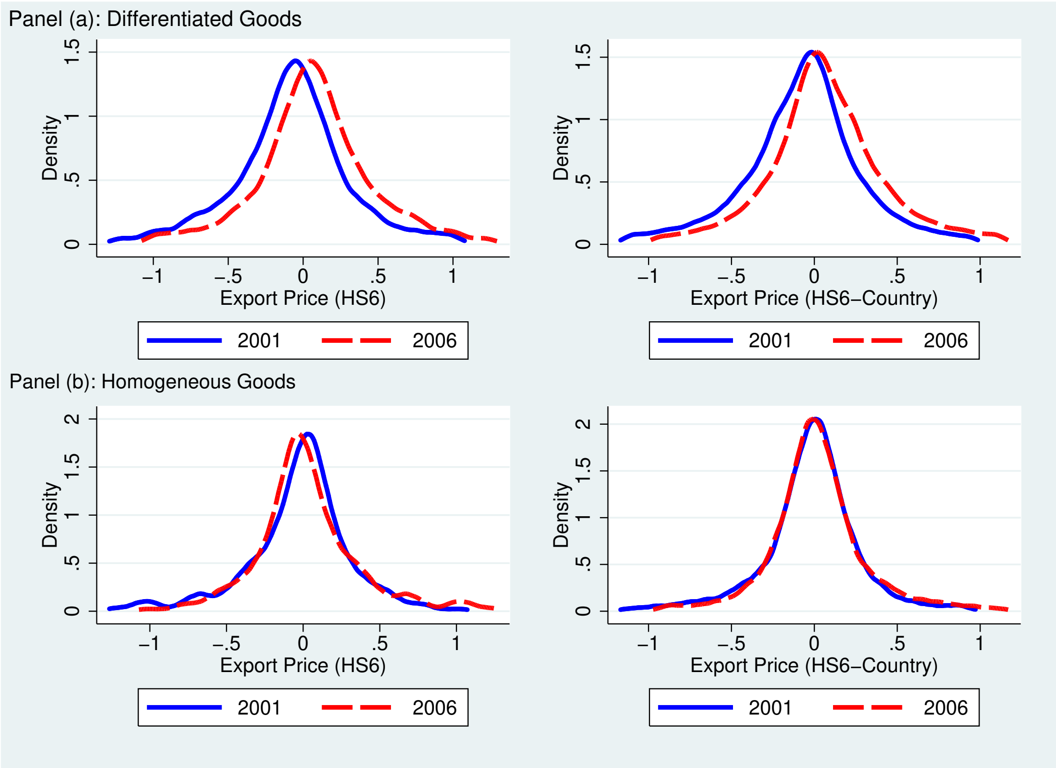

Figure 2: Distribution of Export Prices by Product Differentiation (2001 vs. 2006)

(Rauch, 1999), we use differentiated goods and homogeneous goods as proxies for the above two groups, and compute the change in export prices for these two groups of products. Table 2 shows that the price changes of differentiated goods are significantly larger than those of the whole sample and of homogeneous goods. Figure 2 also presents the differential effect of product differentiation on price distributions: the export prices of differentiated goods significantly increase 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) 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:

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

4 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 to import intermediate inputs. A reduction in the tariff on imported intermediate inputs 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). The resulting reduction in the firm's marginal cost has effects that are similar to an increase in the firm's underlying productivity. We allow the firm to choose the quality of the final good that 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.

4.1 Assumptions

As we are interested in how firms behave both within and across industries, we consider the following system of 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 ω, $x(\omega)$ 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. These preferences imply that in a market in which aggregate expenditure is E, the demand for variety ω in industry i 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 with the productivity of the firm producing variety ω given by $\phi(\omega)$. Final output of variety ω is created using bundles of primary factors, $L(\omega)$, and 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

$$Y(\omega) = \chi \phi(\omega) q(\omega)^{-\alpha} L(\omega)^{1-\mu} M(\omega)^{\mu} \tag{2}$$

where $\mu \in (0, 1)$, $\chi = \mu^{\mu}(1 - \mu)^{1-\mu}$, and $\alpha > 0$ implies that a higher quality variety (those with a wide range of attributes) require more physical inputs to generate the same level of output as a lower quality variety. The composite intermediate input is costless assembled from a continuum of intermediates that are 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 $\Psi_i = \exp \left(\int_0^{\infty} b_i(z) \ln b(z) dz \right)$, $m(z)$ 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, measured in terms of bundles of the primary inputs is 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 indicate that the scope for quality differentiation is limited.

4.2 Implications

Choosing a bundle of primary factors as the numeraire, the cost of production of a variety of final output of a firm of productivity ϕ operating in industry i facing technology given by (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 from a foreign supplier. If the firm purchases intermediate z locally, it pays the domestic unit price $c_m^d(z)$. Alternatively, the firm may incur a fixed cost, f_m, measured in terms of primary factors that gives the firm access to the market for foreign produced inputs. 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 one 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 $\lim_{z\to\infty} A(z) > 0$. 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

$$\tau A(z^*) = 1. \tag{5}$$

It follows that the cost of a bundle of imported intermediates is given by

$$P_i^m = \exp\left(\int_0^{z^*} b_i(z)\ln\left(\tau c_m^f(z)\right)dz + \int_{z^*}^\infty b_i(z)\ln c_m^d(z)dz\right). \tag{6}$$

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

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

where demand $x_i(q, p, \omega)$ is given by (1) and marginal cost C_i is given by (4).[9] Note that we have neglected the domestic market as it is largely irrelevant to our econometric analysis.[10] 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

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

$$p(\phi, P_i^m) = \frac{\sigma_i}{\sigma_i - 1} (\Lambda_i)^{\frac{\alpha}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}} \left(\frac{(P_i^m)^\mu}{\phi} \right)^{\frac{\beta_i - \eta_i}{\beta_i - \eta_i + \alpha(\sigma_i - 1)}}, \tag{8}$$

where $\Lambda_i \equiv \nu_i \left(\frac{E P_i^{\sigma - 1}}{f} \right) \left(\frac{\eta_i - \alpha(\sigma_i - 1)}{\beta_i \sigma_i} \right) \left(\frac{\sigma_i}{\sigma_i - 1} \right)^{1 - \sigma_i}$ is a constant that is common to all firms in industry i. Equations (7) and (8) combined with (4) and (6) fully determine the variables of interest.

We begin our analysis by differentiating (6) with respect to τ to obtain

$$\frac{\tau}{P_i^m} \frac{dP_i^m}{d\tau} = \int_0^{z^*} b_i(z) dz + b_i(z^*) \left[\ln \left(\tau c_m^f(z^*) \right) - \ln c_m^d(z^*) \right] \tau \frac{dz^*}{d\tau} > 0, \tag{9}$$

where $dz^*/d\tau < 0$ is obtained by differentiating (5). The first term on the right-hand side is the intensive margin effect of a change in tariffs while the second term is the extensive margin effect. Note that the extensive margin effect is second-order and vanishes for small $d\tau$ as can be seen from (5). Now, simple differentiation of equations (7) and (8) establishes the following two propositions.

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

Proposition 2. *A reduction in the tariff, τ, induces an incumbent importer/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 ($\beta_i > \eta_i$).*

The results presented in the propositions are intuitive. Consider first proposition one. 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 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.

[9] 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 dataset would have incurred these costs.

[10] It is worth mentioning that in the data firms produce multiple products for multiple locations making it generally impossible to connect input usage to outputs.

Now consider proposition two. 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 where the benefit of expanding sales through selling more units is relatively more important.

4.3 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 (7) and (8) yields the basis of our analysis:

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

$$\Delta \ln p(\phi, P_i^m) = \frac{\beta_i - \eta_i}{\beta_i - \eta_i + \alpha(\sigma_i - 1)} \left(\mu \Delta \ln(P_i^m) - \Delta \ln \phi\right), \tag{11}$$

where

$$\Delta \ln(P_i^m) = \sum_{z \in Z} b_i(z) \Delta \ln \tau(z) + \sum_{z \in Z'} b_i(z) \left(\ln \left[\tau'(z) c_m^f(z)\right] - \ln c_m^d(z)\right) \tag{12}$$

is the empirical analog of (9) 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.[11]

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 (10) and (11) 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.

[11] We include both intensive margin and extensive margin in one of the alternative tariff measures and our results are robust. Please see Section 5.2 for details of constructing alternative tariff measures and Section 7.1 for robustness results.

5 Empirical Specifications and Measurement

In this section, we specify our econometric models and the data that is used to estimate them.

5.1 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.

5.1.1 Price Equations

As noted earlier, our theory relates export prices to import tariffs through equations (11) and (12). We will estimate two types of econometric models motivated by these equations that differ in whether they are estimated in levels or in long-differences. These equations are respectively given by

$$\ln(p_{fh(c)t}) = \beta_\tau Duty_{ft} + \boldsymbol{\beta}_f \boldsymbol{\chi}_{ft} + \beta_i HHI_{it} + \varphi_{fh(c)} + \varphi_t + \epsilon_{fh(c)t}, \tag{13}$$

and

$$\Delta \ln(p_{fh(c)}) = \beta_\tau \Delta Duty_f + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_f + \beta_i HHI_i + \epsilon_{fh(c)}, \tag{14}$$

where $p_{fh(c)}$ 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 the key explanatory variable, $Duty_f$, is import tariff faced by firm f, which is computed by aggregating all import tariffs across firm f's intermediates (see Section 5.2 for details). In addition to these key variables, we include a vector of firm level controls, $\boldsymbol{\chi}_f$, and an industry level measure of competition, the Herfindahl index, HHI_i. When we estimate the model in levels, we include firm-product-country and time dummies. When estimating the model in long-differences, Δ denotes a change in any variable during a five-year period, i.e, between 2006 and 2001.[12]

We will focus on the long difference specification given by (14). Adjustment to the shock of trade liberalization may be slow and there may be issues of autocorrelation when estimating the model in levels (see, for instance, Trefler (2004)). Results associated with shorter differences are qualitatively similar, however, and are reported in Appendix A.3.

The vector $\boldsymbol{\chi}_f$ consists of the observables at firm level that potentially impact 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), total wage bill, and the number of imported varieties.[13] We also control for the any effect of changing competition

[12] It means that for any variable x, $\Delta x \equiv \Delta x_{t-(t-5)} \equiv x_t - x_{t-5} = x_{2006} - x_{2001}$.

[13] It is worth mentioning that, by adding the change in the number of imported varieties, we partially control for the extensive margin effect.

within industry i by adding Herfindahl index, HHI_i, computed at the 4-digit CIC (Chinese Industrial Classification) industry level in the initial year 2001. As the variable of interest in equation (14) is the change in firm-level tariffs, $\Delta Duty_f$, we also cluster error terms at firm level to address the potential correlation of error terms within each firm across different products over time. 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.

We estimate (13) and (14) at various levels of aggregation in order to infer how changes in the composition of a firm's export destinations might vary over time. Our main focus will be at the firm-product-country level, but we will also consider weighted average of export prices across export destinations. By contrasting the coefficient estimates in these two different samples, we can obtain a feel for how important changes in the portfolio of export destinations were over this period of time. In addition, we adopt an variant of equation (14), with dependent variable Δp_f representing the price change at the firm level. Δp_f is a firm-level price change index, constructed by using a Tornqvist index, as in Smeets and Warzynski (2013):

$$\Delta p_f = \sum_h \bar{s}_{fh} \Delta \ln(p_{fh}) \tag{15}$$

where

$$\Delta \ln(p_{fh}) = \ln(p_{fht}) - \ln(p_{fh(t-5)})$$

and

$$\bar{s}_{fh} = \left(s_{fht} + s_{fh(t-5)}\right)/2$$

where 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. Contrasting the results obtained using this data with data at other levels of aggregation in the firm again allows us to assess compositional shifts within the firm across products.

5.1.2 Quality Equations

Quality can only be inferred indirectly from observed prices and demands given explicit functional forms. Following Khandelwal et al. (forthcoming), 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 following empirical demand equation:

$$x_{fhct} = q_{fhct}^{\eta} p_{fhct}^{-\sigma} P_{ct}^{\sigma-1} Y_{ct} \tag{16}$$

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 above equation, and then use the residual from the following OLS regression to infer quality:

$$\ln(x_{fhct}) + \sigma \ln(p_{fhct}) = \varphi_h + \varphi_{ct} + \epsilon_{fhct} \tag{17}$$

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 $\eta \ln(\hat{q}_{fhct}) = \hat{\epsilon}_{fhct}$. Consequently, quality-adjusted prices are the observed log prices less estimated effective quality, i.e., $\ln(p_{fhct}) - \eta \ln(\hat{q}_{fhct})$, 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.[14] Given the value of the elasticity of substitution σ, we are able to estimate quality from equation (17).

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 $\sigma \in [5, 10]$.[15] In our estimation, 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).[16] After obtaining estimated quality, we use the change in estimated quality as dependent variable in equation (14) to examine the effect of tariff reductions on quality upgrading.

5.2 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 the effective tariff reductions that are actually faced by firms properly. There are many ways to aggregate tariffs on intermediate inputs that 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.[17] On the other hand, one can construct industry-level measures that better capture the potential to import more intermediates and which are arguably orthogonal to firm-specific characteristics, but which may miss much of the action on the intensive margin. Given these concerns, we consider a wide range of tariff measures that collectively can paint a more comprehensive picture of the effect of trade liberalization on export upgrading. Nevertheless, given the theoretical appeal of

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

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

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

[17] Of course, instrumental variables can be used to remedy some of these problems but require other orthogonality assumptions.

firm-specific measures, we focus primarily on firm-specific measures.

We begin by describing the construction of our firm-specific measures. We consider several different formulations of these measures which have various different strengths and weaknesses beginning with those that are most closely motivated by our model. According to our theoretical derivation (see the first term in the right hand side of equation (12) in Section 4.3), we compute a firm-specific measure of tariff reductions, $\Delta \ln \tau = \sum_{h \in Z} w_h \Delta \ln \tau_h$, 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.[18] We define $\Delta \ln \tau \equiv \Delta Duty$ since $\tau > 1$ is one plus the tariff rate. In computing the firm-specific tariff reduction, $\Delta Duty$, we use an approximation that at product level $\Delta \ln \tau_h \approx \Delta Duty_h$.[19] This firm-specific input tariff reduction measure is theoretically justified, and can reflect the changes in effective tariffs faced by each firm due to its responses to trade liberalization when the firm alters its input bundles over time.[20]

In addition to this baseline specification of $\Delta Duty$, we adopt four alternative measures of firm-specific tariff reductions to illustrate the robustness of our results. First, to ensure that the effective tariff change is solely driven by the exogenous changes in tariffs, we compute unweighted firm-specific tariff change, $\Delta Duty = \sum_{h \in Z} \Delta Duty_h$. Second, to take into account the potential impact of extensive margin (see the second term in the right hand side of equation (12)), we include the extensive margin into the total set of imported varieties. Then, the firm-specific tariff reduction $\Delta Duty$ is computed as the arithmetic mean of product-level tariff reductions across all imported varieties in both the intensive and the extensive margins. 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. By fixing the total number of imported varieties over the sample period, this measure focuses on the pure changes in tariffs rather than the changes in input bundles (Ge et al., 2011). Third, to consider only imported intermediate inputs, we drop all imported final goods and compute the weighted firm-specific import tariff change in intermediate goods. The final goods and intermediate goods are defined by the Broad Economic Categories (BEC) classification. Note this measure of tariff reduction generates smaller sample size as it loses those firms that only import final goods as inputs to produce exported products.[21] Fourth, we follow Manova and Zhang (2012b) to focus on foreign inputs in the same broad industry classification as the output product. For example, if a firm buys brakes and safety seat belts and sells cars, both its

[18] We only use the import share as weight because there is lack of information on domestic intermediates in Chinese data.

[19] Note that $\Delta \ln \tau_h = \Delta \ln(1 + Duty_h) \approx \Delta Duty_h$, according to $\ln(1 + x) \approx x$.

[20] 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.

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

exports and imports would be recorded in the motor vehicles industry. The average ad valorem duty reduction in its imported inputs such as brakes and safety seat belts would be a proxy for the import tariff change faced by the firm that produces cars. If the company also manufactures cell phones, tariff reduction in SIM cards would enter the measure of import tariff change of its cell phones but not that of its cars. Therefore, for each exported product by a particular firm, we construct the weighted average tariff change across all the inputs imported by the firm (e.g. brakes, safety seat belts) in a given HS2 category (e.g. motor vehicle). We then assign this average tariff change to all products exported by this firm in the same HS2 category (e.g. cars and potentially trucks). Therefore, using this method we eventually compute firm-product specific tariff change $\Delta Duty_{fh}$ for each product h exported by firm f.[22] Among all the four alternative firm-specific tariff reduction measures, this one generates the smallest sample size as it loses those exported products that have no imported inputs in the same HS2 category.

Finally, we also compute changes in industry input and output tariffs using input-output tables as is common in the literature. In addition to the benefits discussed earlier of using industry rather than firm-specific measure, including specifications that use industry tariffs has the benefit of making our results comparable to the literature.

5.3 Productivity

To control for the change in firm productivity in some of our regressions, we estimate both total factor productivity (TFP) and labor productivity (measured by value added per worker). For TFP, our main results are based on the augmented Olley-Pakes (hereafter OP) method (Olley and Pakes, 1996), but using other methods to estimate productivity does not alter the main results.[23]

Our OP estimation approach builds upon the recent development in augmenting the original OP method, including Amiti and Konings (2007), Feenstra et al. (forthcoming), and Yu (2011), to deal with the simultaneity bias and selection bias. We use deflated value-added to measure production output. To measure real terms of firm's inputs (labor and capital) and value added, we use different input price deflators and output price deflators from Brandt et al. (2012).[24] The output deflators are constructed using "reference price"information from China's Statistical Yearbooks, and the input deflators are constructed based on output deflators and China's national input-output table (2002). Then we construct the real investment variable by adopting the perpetual inventory method to investigate the law of motion for real capital and real investment. To capture the depreciation rate, we use each firm's real depreciation rate provided by the NBSC firm-production database.

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

[23] Our results are robust to different approaches in estimating TFP, including the OLS method, the Levinsohn-Petrin method (Levinsohn and Petrin, 2003), and the Ackerberg-Caves-Frazer augmented O-P method (Ackerberg et al., 2006). To save space, the results based on different TFP estimates are not reported in the main text but available upon request.

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

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

6 Main Results

In this section, we present the results of estimating variants of equations (14) and (17) using a sample of ordinary Chinese manufacturing exporters, i.e. those that are not part of the export processing regime that allows firms to import intermediates tariff-free. We will show in a robustness check in section 7, that as one would expect export processing firms are not affected by falling tariffs. 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.

6.1 Import Tariffs and Export Prices

Table 3 reports the results of our baseline regression, equation (14). We first discuss the results associated with long differences at the firm-product-destination level shown in columns 1-3. 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 price at firm-product-destination level by 4.8 percent.

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 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 both 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. 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 that TFP increase being the result of producing higher quality. Second, the coefficient on $\Delta \ln$(Import Varieties) is positive but is not statistically significant. The lack of statistical significance may be due to the high correlation between this variable and $\Delta Duty$.

Columns 4-6 report the results with the price change at firm-product level as dependent variable, and columns 7-9 report the results based on the firm-level price change as dependent variable. Not surprisingly, 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.

Table 3: Basic Results (Long-difference Estimation, 2006-2001)

	Dependent Variable								
	$\Delta \ln(\text{Export Price}_{fhc})$			$\Delta \ln(\text{Export Price}_{fh})$			$\Delta\text{Export Price Index}_f$		
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	14439	14439	14439	7595	7595	7595	2368	2368	2368
R-squared	.001	.003	.004	.001	.004	.005	.002	.007	.007

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (2001) at the 4-digit CIC industry in China.

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.1 in Appendix).[25] These significantly negative coefficients on tariff reductions support the prediction of Proposition 2 that a tariff reduction induces an incumbent importer/exporter to raise its export price in industries

[25] When we use one-year difference, the coefficients on $\Delta Duty$ are nonsignificant, perhaps due to insufficient time for firms to respond to trade liberalization, and therefore are not included in Table A.1.

where the scope for quality differentiation is large. As to the opposite prediction where the scope for quality differentiation is small, we leave to Section 6.3 for further discussion.

6.2 Import Tariffs and Export Quality

The key mechanism of our model is the choice of quality. The results in Table 3 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 4: Effect of Tariff Reductions on Quality Upgrading

	Dependent Variable: $\Delta\ln(\hat{q}_{fhc})^{\eta}$					
	$\sigma=5$		$\sigma=10$		$\sigma=\sigma_i$	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-3.866**	-3.906**	-7.057***	-7.359***	-8.370***	-8.567***
	(1.577)	(1.567)	(2.590)	(2.600)	(2.760)	(2.790)
Δln(TFP)		0.377***		0.551***		0.440***
		(0.079)		(0.131)		(0.130)
Δln(Capital/Labor)		0.199*		0.256		0.136
		(0.110)		(0.178)		(0.166)
Δln(Labor)		0.328***		0.233		0.156
		(0.115)		(0.181)		(0.177)
Δln(Wage)		0.187		0.278		0.0288
		(0.138)		(0.232)		(0.219)
Δln(Import Varieties)		0.147*		0.201		0.208
		(0.080)		(0.139)		(0.136)
HHI		-2.113		-4.874		-5.181
		(1.876)		(3.226)		(3.904)
Observations	14439	14439	14439	14439	14439	14439
R-squared	.001	.007	.001	.006	.002	.004

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (2001) at the 4-digit CIC industry in China.

Table 4 reports the estimation results of equation (14) with the change in estimated effective quality as dependent variable. Different columns correspond to using different values of elasticity of substitution in estimating quality. Note that all coefficients on tariff reductions are significantly negative, 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 and the signs are similar to those in the baseline regressions in Table 3. Also, the coefficients on the number of imported varieties are insignificant when we use industry-specific elasticities of substitution, indicating that the control for changes on the extensive margin of importing does not significantly affect export quality. Moreover, we add 2-digit CIC industry fixed effects into the baseline regressions on prices and quality (as in Tables 3 and 4), and report similar results in Table A.2 in Appendix.

Then we test the prediction of Proposition 2 for the situation when quality differentiation is small. We report the estimation results of equation (14) with the change in estimated effective quality-adjusted price, $\ln(p_{fhct}) - \eta \ln(\hat{q}_{fhct})$, as dependent variable, in Table A.3 in Appendix. By construction, the quality-adjusted price has sorted out the quality effect and should fall in the category where the scope for quality differentiation is small. Therefore, according to Proposition 2 that a reduction in import tariff induces an incumbent importer/exporter to lower its export price in industries where the scope for quality differentiation is small, we expect positive coefficients on ΔDuty. The results in Table A.3 confirm this prediction: the coefficients on ΔDuty in Table A.3 are all positive.[26]

6.3 The Role of Quality Differentiation

According to Proposition 2, the effect of tariff reduction on export price 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 in the real data, the price change for homogeneous goods is nonsignificant and ambiguous.

To test whether the scope for quality differentiation indeed matters, first, we create two separate samples, one composed of differentiated goods and the other composed of homogeneous goods, based on Rauch's (1999) classification, to proxy for goods with large and with small scope for quality differentiation, respectively (see Appendix for more 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 decreases 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

$$\Delta \ln(p_{fhc}) = \beta_\tau \Delta Duty_f + \beta_H \Delta Duty_f \times HOMOGENEOUS_h + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_f + \beta_i HHI_{i(2001)} + \epsilon_{fhc}, \quad (18)$$

where $HOMOGENEOUS_h$ is a dummy variable which is equal to one for homogeneous goods and zero for differentiated goods. The coefficient on the interaction term, β_H, is of our interest. We expect a positive β_H and a negative β_τ. We also estimate the quality equation with the change in estimated effective quality $\Delta \ln(\hat{q}_{fhc})^\eta$ as the dependent variable in (18).

Table 5 reports the estimation results of the above approaches. Columns 1-3 report estimation results when we regress the change in (log) price for HS6-country product on tariff reductions; columns

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

Table 5: Effect of Tariff Reductions (Differentiated vs. Homogeneous Goods)

	Dependent Variable								
	$\Delta\ln(p_{fhc})$			$\Delta\ln(\hat{q}_{fhc})^{\eta}$			$\Delta\ln(p_{fh})$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	-0.653***	0.527	-0.695***	-10.530***	5.271	-10.250***	-1.021***	0.832*	-1.005***
	(0.248)	(0.392)	(0.231)	(3.135)	(4.045)	(2.950)	(0.318)	(0.475)	(0.290)
ΔDuty $\times HOMOGENEOUS$			1.466***			13.840***			1.841***
			(0.316)			(3.594)			(0.379)
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12805	1634	14439	12805	1634	14439	6620	975	7595
R-squared	.005	.003	.005	.005	.002	.006	.007	.005	.008

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level competition control refers to Herfindahl index (HHI), which is computed in the initial year (2001) at the 4-digit CIC industry in China. Firm-level controls include the changes between 2006 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

4-6 report regression results with the change in (log) estimated quality for HS6-country product as dependent variable; columns 7-9 report the results with the change in (log) price for HS6 product as dependent variable. In each of the three columns, the first column uses the subsample of differentiated products and therefore presents the 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 (18) 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) 5 percent level. The results are consistent with our expectation and further substantiate Propositions 1 and 2.

We now check the robustness of our results to alternative measures for the scope of quality differentiation within an industry by adopting two alternative measures, Rauch index and Gollop-Monahan index. The Rauch index is still based on Rauch's (1999) classification but computed as a fractional value at industry level, while the Gollop-Monahan index measures the dissimilarity of input mixes across firms in an industry and is defined for the relevant intermediate-input sector. 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 response to tariff reductions through both intensive and extensive margins of their intermediates. Higher value of Rauch index or Gollop-Monahan index indicates larger scope for product quality differentiation. These measures have been used by some previous studies, including Kugler and Verhoogen (2012), Tang and Zhang (2012), among others. Both measures are obtained from Kugler and Verhoogen (2012) and the detailed

[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.

description is contained in Appendix A.2.

Table 6: The Role of Quality Differentiation: Rauch Index and G-M (Gollop-Monahan) Index

	Dependent Variable					
	$\Delta\ln(p_{fhc})$		$\Delta\ln(\hat{q}_{fhc})^{\eta}$		$\Delta\ln(p_{fh})$	
	(1) Rauch	(2) G-M	(3) Rauch	(4) G-M	(5) Rauch	(6) G-M
Panel A:						
ΔDuty $\times$ DIFF^{High}	-0.765***	-0.750***	-13.390***	-11.060***	-0.985***	-1.352***
	(0.263)	(0.247)	(3.621)	(2.899)	(0.297)	(0.336)
ΔDuty $\times$ DIFF^{Low}	-0.020	0.261	-0.007	0.345	-0.008	0.422
	(0.310)	(0.320)	(2.818)	(3.821)	(0.412)	(0.359)
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Observations	12963	12963	12963	12963	7595	6757
R-squared	.005	.006	.007	.007	.007	.010
Panel B:						
ΔDuty	0.939**	1.113	8.774**	13.010	1.070**	1.835*
	(0.413)	(0.859)	(3.782)	(11.179)	(0.497)	(1.096)
ΔDuty $\times$ DIFF_Index	-1.599***	-2.938*	-18.930***	-38.900*	-2.178***	-4.790**
	(0.436)	(1.540)	(4.638)	(20.231)	(0.523)	(2.022)
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Observations	12963	12963	12963	12963	6757	6757
R-squared	.005	.005	.006	.005	.008	.007

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level competition control refers to Herfindahl index (HHI), which is computed in the initial year (2001) at the 4-digit CIC industry in China. Firm-level controls include the changes between 2006 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

Table 6 reports estimation results based on Rauch index and Gollop-Monahan index. In Panel A and B, we estimate the following two equations, respectively:

$$\Delta\ln(p_{fhc}) = \beta_{High}\Delta Duty_f \times DIFF^{High} + \beta_{Low}\Delta Duty_f \times DIFF^{Low} + \boldsymbol{\beta}_f\Delta\boldsymbol{\chi}_f + \beta_i HHI_i + \epsilon_{fhc}, \quad (19)$$

$$\Delta\ln(p_{fhc}) = \beta_{\tau}\Delta Duty_f + \beta_{Diff}\Delta Duty_f \times DIFF\_Index + \boldsymbol{\beta}_f\Delta\boldsymbol{\chi}_f + \beta_i HHI_i + \epsilon_{fhc}, \quad (20)$$

where $DIFF^{High}$ is equal to 1 if the quality differentiation index value is above its median (i.e., representing industries with larger scope for quality differentiation) and 0 otherwise; $DIFF^{Low}$ is equal to 1 if the index value is below its median (i.e., representing industries with smaller scope for quality differentiation) and 0 otherwise; $DIFF\_Index$ is the value of either Rauch index or Gollop-Monahan index. As in Table 5, we replace the dependent variable $\Delta\ln(p_{fhc})$ with HS6 product-level price $\Delta\ln(p_{fh})$ (columns 5 and 6) or estimated effective quality $\Delta\ln(\hat{q}_{fhc})^{\eta}$ (columns 3 and 4) and estimate the variants of equations (19) and (20).

In Panel A of Table 6, the coefficients on the two interaction terms, β_{High} and β_{Low}, are of our interest. We expect a negative, more significant β_{High} and a nonsignificant β_{Low}. The implication is that tariff reductions induce firms to increase quality and export price in an industry where the scope for quality differentiation is large. In Panel B, the variable $DIFF\_Index$ is continuous, and therefore, we expect the coefficient on $\Delta Duty_f \times DIFF\_Index$, β_{Diff}, to be significantly negative, and the sum of β_τ and β_{Diff} to be less than zero. The results in Table 6 are fully consistent with our expectation, validating the role of quality differentiation in the effect of tariff reductions on price and quality.

7 Robustness

We conduct six robustness checks. First, we present the results based on alternative measures of tariffs, including industry input/output tariffs. Second, we use instrumental variable estimation to address the potential issue of endogenous tariff reductions. Third, we provide more cross-sectional evidence about the relationship between tariffs and export prices. Fourth, we show that our results regarding the price increase are not sensitive to currency appreciation. Fifth, we use processing exporters as comparison group to show that our quality upgrading mechanism is specific to ordinary exporters because processing trade firms do not pay tariffs. Last, but not least, we confirm that our results are not biased towards big firms using the whole customs data without matching to the manufacturing firm survey.

7.1 Alternative Measures of Tariff

The results of alternative firm-specific tariff reduction measures are shown in Table 7 and the results of industry-level tariff measures in Table 8.

In Table 7 different columns correspond to different measures of the tariff (see detailed description in Section 5.2). Specifications 1 and 2 use unweighted firm-specific tariff reductions; specifications 3 and 4 adopt the tariff reduction measure as in Ge et al. (2011) by fixing the total number of imported varieties during the whole sample period; specifications 5 and 6 employ the weighted firm-specific import tariff reductions of only intermediate goods; specifications 7 and 8 use the tariff reduction measure constructed by following the mapping between inputs and outputs as in Manova and Zhang (2012b). 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, 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, except for using measure 4, implying that the effect of import tariff reduction on export price increase is more significant for products in industries where the scope for quality differentiation is large. The results are far stronger for measures of tariff reduction that allow different input tariffs to receive different weights. This indicates that allowing for crucial inputs to receive a higher weight is important: large tariff reductions have a bigger impact the more

Table 7: Alternative Firm-Specific Tariff Reduction Measures

	Firm-specific Tariff Reduction Measures							
	Measure 1		Measure 2		Measure 3		Measure 4	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: dependent variable $= \Delta \ln(p_{fh})$								
ΔDuty	-0.658*	-0.778**	-1.131**	-1.090*	-0.619**	-0.884***	-0.197	-0.227
	(0.350)	(0.349)	(0.574)	(0.563)	(0.276)	(0.286)	(0.314)	(0.331)
ΔDuty × HOMOGENEOUS		1.880***		2.003***		1.884***		0.198
		(0.494)		(0.552)		(0.440)		(0.512)
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	7595	7595	7595	7595	6830	6830	4302	4302
R-squared	.005	.006	.005	.006	.003	.005	.007	.007
Panel B: dependent variable $= \Delta \ln(p_{fhc})$								
ΔDuty	-0.213	-0.273	-0.808*	-0.798*	-0.581***	-0.770***	-0.103	-0.161
	(0.273)	(0.272)	(0.452)	(0.450)	(0.221)	(0.233)	(0.271)	(0.282)
ΔDuty × HOMOGENEOUS		1.480***		1.649***		1.668***		0.611
		(0.415)		(0.479)		(0.366)		(0.456)
Industry-level Competition Controls	yes	yes	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	14439	14439	14439	14439	12947	12947	8859	8859
R-squared	.003	.004	.004	.005	.004	.006	.006	.006

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (2001) at the 4-digit CIC industry in China. Firm-level controls include the changes between 2006 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment). By construction, tariff measure 3 yields fewer observations in the sample; tariff measure 4 provides fewest observations and thus presents the smallest sample size.

that intermediate is used in production, i.e. the intensive margin is the primary channel at work.

Table 8 reports the results based on industry input and output tariffs. Columns 1-4 present the results using the price change for HS6-country product as dependent variable, and columns 5-8 report the results with the price change for HS6 product. When we regress the price change on the industry output tariff change (see columns 1 and 5), the coefficients on output tariff are negative yet insignificant. The negative sign of coefficients on output tariff is consistent with the literature that lower output tariffs can increase productivity by inducing tougher competition (e.g., Amiti and Konings, 2007) and thus increase prices according to the quality-and-trade literature. When we regress the price change on industry input tariffs (see columns 2 and 6), the coefficients on input tariff are significantly negative, implying that lower input tariffs can raise export prices through quality effect. When we include both input and output tariff as explanatory variables, the effect of input tariff, the key variable of our interest, is still significantly negative (see columns 3 and 7), which further confirms that input tariff reductions raise export prices. Lastly, we estimate equation (18) 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 large scope for quality differentiation while in industries with small scope for quality differentiation the price increase is significantly smaller. Thus, adopting industry-level tariffs does not alter our results.

Table 8: Industry Input and Output Tariffs

	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	14439	14439	14439	14439	7595	7595	7595	7595
R-squared	.003	.005	.005	.006	.004	.005	.005	.006

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the HS6 product level in parentheses, because we use the concordance between HS6 products and Chinese input-output sector to compute industry input/output tariffs. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (2001) at the 4-digit CIC industry in China. Firm-level controls include the changes between 2006 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

7.2 Instrumental Variable Estimation

Now, we address the issue of the potential endogeneity of tariff changes. We use two methods to conduct instrumental variable estimation and report the results in Table 9. In specifications 1 and 2, we employ the 1997 tariff level as the fixed past level to instrument the change in tariffs between 2006 and 2001; in specifications 3 and 4, we use the initial level to instrument the change, i.e., we use the 2001 tariff level to instrument $\Delta Duty_{2006-2001}$. Again, we report results for both firm-product-country prices in Panel A and firm-product prices in Panel B.

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

Table 9 clearly illustrates that in all specifications, the coefficients on the interaction terms (ΔDuty × $HOMOGENEOUS$) are significantly positive, and the coefficients on tariff change are all significantly negative, at 1 percent significance level. This is consistent with the main predictions of our model that tariff reductions lead to higher export prices while this effect increases in product differentiation and thus, the goods with small scope for quality differentiation have a smaller increase, or even a reduction, in their export prices.

Table 9: Instrumental Variable Estimation

	instrumented by $Duty_{1997}$		instrumented by $Duty_{2001}$	
	(1)	(2)	(3)	(4)
Panel A: dependent variable $= \Delta\ln(p_{fhc})$				
ΔDuty	-1.339***	-1.542***	-1.339***	-1.542***
	(0.405)	(0.402)	(0.405)	(0.402)
ΔDuty ×$HOMOGENEOUS$		2.066***		2.066***
		(0.381)		(0.381)
Industry-level Competition Control	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes
Kleibergen-Paap rk LM χ^2 statistic	107.266†	111.730†	107.266†	111.730†
Kleibergen-Paap rk Wald F statistic	239.197†	124.807†	237.197†	124.807†
Observations	14439	14439	14439	14439
R-squared	.002	.004	.002	.004
Prob > F	.000	.000	.000	.000
Panel B: dependent variable $= \Delta\ln(p_{fh})$				
ΔDuty	-1.539***	-1.821***	-1.539***	-1.821***
	(0.509)	(0.498)	(0.509)	(0.498)
ΔDuty ×$HOMOGENEOUS$		2.246***		2.246***
		(0.457)		(0.457)
Industry-level Competition Control	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes
Kleibergen-Paap rk LM χ^2 statistic	94.272†	99.725†	94.272†	99.725†
Kleibergen-Paap rk Wald F statistic	200.338†	110.314†	200.338†	110.314†
Observations	7595	7595	7595	7595
R-squared	.004	.006	.004	.006
Prob > F	.001	.000	.001	.000

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. † indicates significance of p-value at the 0.1 percent level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Industry-level Competition Control refers to Herfindahl index (HHI), which is computed in the initial year (2001) at the 4-digit CIC industry in China. Firm-level controls include the changes between 2006 and 2001 in the following variables: TFP, the number of imported varieties, capital intensity, average wage, and firm size (measured by total employment).

The fact that coefficients in the IV regressions are considerably larger than the OLS coefficients could have multiple explanations. On the one hand, this could simply be an issue of measurement error as relating tariff reductions to marginal costs of individual products within the firm is by necessity indirect. On the other hand, it could be that the firms that faced the highest average tariffs on their imported intermediates were those with the greatest potential for increasing their product quality once tariffs came down.

7.3 Cross-sectional Pattern with Industry Tariffs

To provide more evidence on the relationship between tariffs and export prices, we also conduct the baseline regression in levels (see equation (13)) with industry input/output tariffs to present the cross-sectional patterns in Table 10.[28] Columns 1-3 and 4-6 present the results with export prices for HS6-country product and HS6 product, respectively. In separate regressions, the coefficients on output tariffs and on input tariffs are both significantly negative (see columns 1-2 and 4-5); in combined regressions, the effect of input tariffs are still significantly negative (see columns 3 and 6). As input tariff is of our interest, this further provides evidence on the negative relationship between the levels of export prices and the levels of input tariffs, i.e., cross-sectionally speaking, higher export prices are also associated with lower input tariffs.

Table 10: Regressions in Levels with Industry Input/Output Tariffs

	Industry Input/Output Tariff					
	Dependent variable: $\ln(p_{fhct})$			Dependent variable: $\ln(p_{fht})$		
	(1)	(2)	(3)	(4)	(5)	(6)
$Duty^{output}$	-0.409***		0.344***	-0.738***		0.0457
	(0.087)		(0.115)	(0.145)		(0.196)
$Duty^{input}$		-1.457***	-1.814***		-1.633***	-1.678***
		(0.137)	(0.182)		(0.209)	(0.283)
Year fixed effects	yes	yes	yes	yes	yes	yes
Firm-product-country fixed effects	yes	yes	yes			
Firm-product fixed effects				yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes
Observations	1161028	1161028	1161028	420034	420034	420034
R-squared	.981	.981	.981	.969	.969	.969

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

7.4 Sensitivity to Currency Appreciation

Our main results show that export prices increase with tariff reductions in China. Note that our export price is denominated in US dollars. However, one may be concerned that the price increase is partially due to the appreciation of *Renminbi* (Chinese currency, hereafter RMB). It is possible that a stronger RMB reduces firms' costs to purchase imported inputs with local currency, and thus provides firms more incentive to switch to better inputs. To test the sensitivity of our results to RMB appreciation,

[28] We present the cross-sectional pattern 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.

we also use the data during the period before the appreciation to test whether export prices indeed increase without currency appreciation. As RMB appreciated in late 2005, we dropped data of 2005 and 2006, and conduct the long-difference estimation of equation (14) and its variants for only one period, i.e., 2004-2001. Consequently, we have a smaller sample size and less significant level, and the year fixed effect term is also omitted. Table 11 reports the results and all coefficients on $\Delta Duty$ are negative, consistent with the prediction for goods with large scope for quality differentiation.

Table 11: Results in Pre-Appreciation Periods (2004-2001)

	Dependent Variable					
	$\Delta\ln(\text{Export Price}_{fhc})$		$\Delta\ln(\text{Export Price}_{fh})$		$\Delta\text{Export Price Index}_f$	
Regressor:	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-0.110	-0.114	-0.424**	-0.422**	-0.289*	-0.288*
	(0.118)	(0.118)	(0.179)	(0.179)	(0.174)	(0.170)
Industry-level Competition Control		yes		yes		yes
Firm-level Controls		yes		yes		yes
Observations	18,809	18,809	9,253	9,253	2,855	2,855
R-squared	.0001	.001	.001	.001	.001	.003

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

Table 12: Comparison Group: Pure Processing Exporters

	Dependent Variable					
	$\Delta\ln(\text{Export Price}_{fhc})$		$\Delta\ln(\text{Export Price}_{fh})$		$\Delta\text{Export Price Index}_f$	
Regressor:	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	0.265	0.256	0.420	0.357	0.122	0.096
	(0.261)	(0.233)	(0.258)	(0.224)	(0.185)	(0.179)
Industry-level Competition Control		yes		yes		yes
Firm-level Controls		yes		yes		yes
Observations	1771	1771	1036	1036	403	403
R-squared	.002	.010	.003	.009	.001	.014

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

7.5 Comparison Group: Processing Exporters

We use processing exporters as comparison group to show that processing firms do not significantly increase export prices, probably because they never pay tariffs to begin with. As some firms are "hybrid" exporters, i.e., they do both ordinary trade and processing trade transactions, we only select those pure processing exporters as comparison. Table 12 reports the results of equation (14) for those pure processing firms, which can be compared with the baseline regressions for ordinary exporters in Table 3. There is no evidence that pure processing exporters increase their export prices in response to tariff reductions.

7.6 Large Sample Test Using Whole Customs Data

So far our empirical results are based on the merged data built upon the NBSC manufacturing survey database and the Customs database. However, the NBSC manufacturing survey only includes above-scale firms, which may lead to sample selection bias. Therefore, to further verify that our results are not biased towards big firms, we replicate baseline regressions with both firm-specific tariff reductions and industry input tariff reductions in Table 13, where Panels A and B present results of export prices at HS6-country level and at HS6 product level, respectively. In each of the six columns, the first five columns correspond to firm-specific measures of tariff reductions and the last one corresponds to industry input tariff reduction measure. Among the five columns of using firm-specific measures of tariff reductions, the first one adopts our main tariff reduction measure, and the rest four employ the four alternative measures of tariff reductions as described in order in Section 5.2. In Table 13, 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.

Table 13: Long-Difference Estimation Based on Whole Customs Data

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: dependent variable = $\Delta \ln(p_{fhc})$						
ΔDuty	-0.477***	-0.162	-0.693**	-0.428***	-0.0690	-0.925***
	(0.156)	(0.191)	(0.295)	(0.155)	(0.157)	(0.338)
ΔDuty × HOMOGENEOUS	1.167***	1.574***	1.950***	1.081***	1.069***	1.728***
	(0.287)	(0.274)	(0.297)	(0.301)	(0.316)	(0.313)
Observations	48100	48100	48100	44237	27924	48100
R-squared	.001	.001	.002	.001	.001	.002
Panel B: dependent variable = $\Delta \ln(p_{fh})$						
ΔDuty	-0.320	-0.544**	-0.901**	-0.406*	-0.280	-0.785**
	(0.211)	(0.236)	(0.386)	(0.225)	(0.179)	(0.318)
ΔDuty × HOMOGENEOUS	1.315***	1.522***	1.711***	1.390***	0.835***	1.554***
	(0.256)	(0.286)	(0.311)	(0.292)	(0.284)	(0.302)
Observations	31250	31250	31250	29234	16316	31250
R-squared	.001	.001	.001	.001	.0004	.001

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors are corrected for clustering at firm level for firm-specific tariff reductions (see columns 1-5) and at HS6 product level for industry input tariff reductions (see column 6) in parentheses.

We also plot the price distribution based on the whole customs data in Figure 3 to confirm the different patterns of price change by product differentiation. Similar as Figure 2 based on the merged data in stylized facts, the price distribution apparently shifts to the right for differentiated goods in Panel A, while this price shifting pattern is nonsignificant or even reversed for homogeneous goods in Panel B.

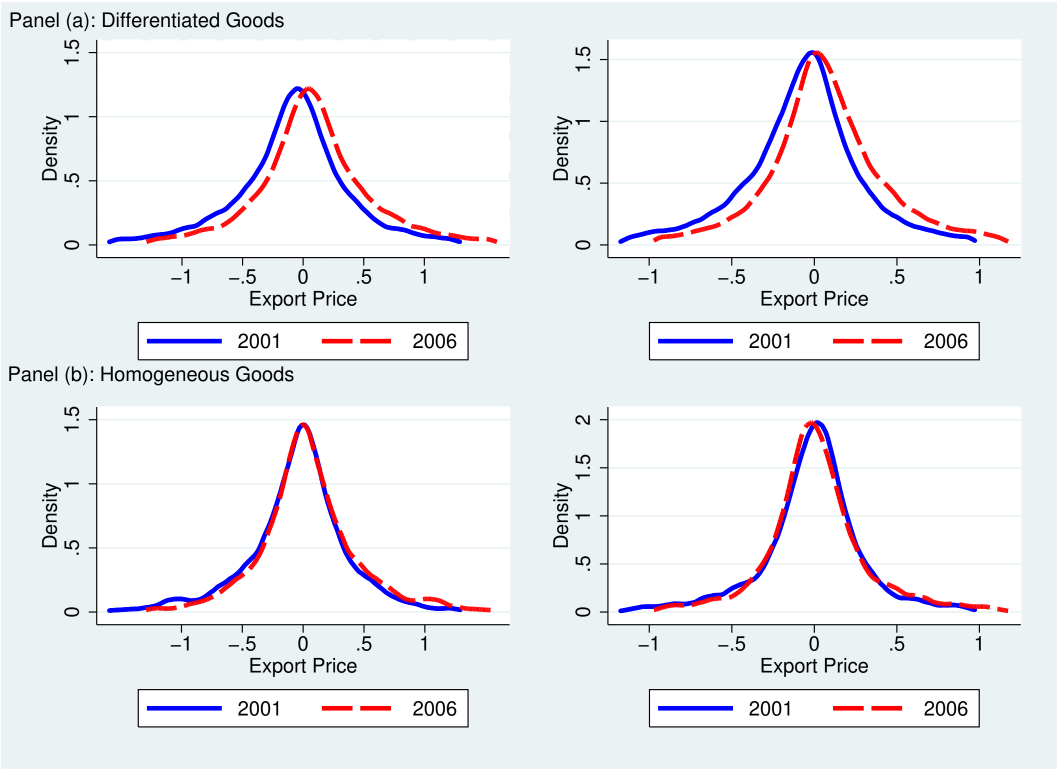

Figure 3: Distribution of Export Prices Based on Whole Customs Data (2001 vs. 2006)
Note: The graphs in the left and the right columns refer to HS6 and HS6-country product, respectively.

8 Conclusion

In this paper, we extend Melitz's (2003) model of trade with heterogeneous firms by introducing endogenous product quality. The model predicts that when the scope for quality differentiation is large, a reduction in import tariff induces firms to choose higher product quality and set higher export prices, and this effect is less significant or even opposite when the scope for quality differentiation is small. These predictions are consistent with the stylized facts based on Chinese data and also verified by different estimation specifications. In particular, our empirical exercises confirm that even at the finest dimension, the firm-product-country level, the quality upgrading effect is significant when firms are facing import tariff reductions. Therefore, we conclude that quality effect is indeed an important channel of the impact of trade liberalization on export prices.

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

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A Appendix

A.1 Data Description

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

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

   1.1 We delete all trade intermediaries from exporting firms. Similar to Ahn et al. (2011) and Tang and Zhang (2012), we identify trade intermediaries by finding the presence of phrases (such as "trading", "exporting", and "importing") in their company names.[29] We further drop all exports under processing trade regime and only keep ordinary trade in our sample.[30]

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

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

   1.4 We deflate the export value using output deflators from Brandt et al. (2012).[31] Note that the deflators in Brandt et al. (2012) are by 4-digit CIC industry in China, while there is no information about CIC industry code in the Customs Data. Therefore, we use the concordance between the Input-Output (I-O) sectors and the HS codes and the concordance between the I-O sectors and the CIC industries by the NBSC to merge each HS code with a CIC industry. Eventually, we are able to compute the deflated value at HS6 level.

   1.5 We estimate product quality and quality-adjusted price by following Khandelwal et al. (forthcoming). See Section 6.2 for details.

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

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

   2.1-2.3 are similar with 1.1-1.3.

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

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

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

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

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

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

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

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

A.2 Measures of Quality Differentiation

- **Rauch's (1999) homogeneous-good dummy**. Source: Rauch (1999).
  At the 4-digit SITC Revision 2 level, Rauch (1999) categorizes industries into three categories: (1) "homogeneous" goods that are mainly traded on organized exchanges; (2) "reference-priced" goods; (3) goods that neither have reference prices nor are traded on organized exchanges. The dummy variable $HOMOGENEOUS$ equals one if the product falls into category (1) or (2) and zero otherwise. We concord the data into HS 6-digit level (2002 version) from SITC Rev.2. The concordance table is from the United Nations Statistics Division.

- **Rauch index**. Source: Kugler and Verhoogen (2012).
  SITC 4-digit sectors classified by Rauch's classification as "homogeneous" or "reference-priced" are assigned 0, others are assigned 1. Kugler and Verhoogen (2012) convert SITC 4-digit industries to ISIC rev. 2 4-digit industries and generate some fractional values, with higher values indicating larger scope for quality differentiation. We then concord the Rauch index from Kugler and Verhoogen (2012) into HS 6-digit level (2002 version) using the concordance table from United Nations Statistics Division.

- **Gallop-Monahan Index** (based on US firms). Source: Kugler and Verhoogen (2012).
  The index is defined as follows:

$$GM_k = \sum_{j,k,t} w_{jt} \left(\sum_i \frac{|s_{ijkt} - \bar{s}_{ikt}|}{2} \right)^{1/2}$$

where i, j, k, and t stand for inputs, plants, industries and years; s_{ijkt} is the expenditure share on input i of plant j in industry k in year t; $\bar{s}_{ikt}$ is the average expenditure share on input i by all plants in industry k in year t; w_{jt} is the share of revenues of plant j in year t in total revenues of all plants in all years in industry k. The term inside the brackets measures how dissimilar input mix of plant j is from other plants in its industry in the corresponding year. The measure then averages those plant-specific measures over plants and years, using revenues as weights. We adopt this measure already constructed by Kugler and Verhoogen (2012) since we do not have complete information on input mix at the firm level in our Chinese data. Their method is building upon Bernard and Jensen (2007). Their original data are available at the ISIC Rev.2. 4-digit level, and we concord to HS6 using the concordance from the UN Comtrade.

A.3 More Tables

Table A.1: Results with Different-period Difference

	Dependent Variable					
	$\Delta \ln(ExportPrice)_{fhct}$			$\Delta \ln(ExportPrice)_{fht}$		
	(1)	(2)	(3)	(4)	(5)	(6)
In 2 period difference: $\Delta Duty_{t-(t-2)}$	-0.180*			-0.255*		
	(0.108)			(0.137)		
In 3 period difference: $\Delta Duty_{t-(t-3)}$		-0.196*			-0.397**	
		(0.119)			(0.173)	
In 4 period difference: $\Delta Duty_{t-(t-4)}$			-0.271**			-0.468**
			(0.153)			(0.200)
Year fixed effects	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Firm-level Controls	yes	yes	yes	yes	yes	yes
Observations	158,616	79,777	37,427	69,040	37,203	18,483
R-squared	0.002	0.002	0.001	0.001	0.002	0.001

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

Table A.2: Effect of Tariff Reductions on Export Prices and Quality with Industry Fixed Effects

	Dependent Variable							
	ΔPrice_{fhc}		$\Delta\text{Quality}_{fhc}$		ΔPrice_{fh}		$\Delta\text{Price Index}_{f}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔDuty	-0.467**	-0.531**	-6.602**	-6.997***	-0.666**	-0.728***	-0.701**	-0.694**
	(0.223)	(0.229)	(2.656)	(2.684)	(0.275)	(0.279)	(0.312)	(0.317)
Δln(TFP)		0.035***		0.320**		0.034**		0.043**
		(0.012)		(0.133)		(0.016)		(0.017)
Δln(Capital/Labor)		0.024		0.173		0.037		0.002
		(0.016)		(0.166)		(0.024)		(0.022)
Δln(Labor)		0.003		0.223		0.017		-0.006
		(0.017)		(0.175)		(0.025)		(0.027)
Δln(Wage)		0.016		0.073		0.029		0.045*
		(0.020)		(0.215)		(0.024)		(0.025)
Δln(Import Varieties)		0.005		0.151		0.013		0.004
		(0.013)		(0.135)		(0.015)		(0.018)
HHI		-0.548*		-5.517*		-0.699*		-0.159
		(0.284)		(3.157)		(0.390)		(0.274)
Industry fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	14439	14439	14439	14439	7595	7595	2368	2368
R-squared	.013	.016	.012	.014	.015	.018	.026	.031

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (2001) at the 4-digit CIC industry in China.

Table A.3: Effect of Tariff Reductions on the Change in Quality-Adjusted Prices

	Dependent Variable: the change in effective quality-adjusted price $\Delta\ln(\widetilde{p}_{fhct}) \equiv \Delta\left[\ln(p_{fhct}) - \eta\ln(\hat{q}_{fhct})\right]$					
	$\sigma = 5$		$\sigma = 10$		$\sigma = \sigma_i$	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	3.385**	3.390**	6.575***	6.842***	7.889***	8.051***
	(1.399)	(1.387)	(2.387)	(2.396)	(2.589)	(2.614)
Δln(TFP)		-0.335***		-0.509***		-0.398***
		(0.070)		(0.120)		(0.120)
Δln(Capital/Labor)		-0.176*		-0.233		-0.113
		(0.097)		(0.163)		(0.152)
Δln(Labor)		-0.327***		-0.232		-0.154
		(0.104)		(0.166)		(0.164)
Δln(Wage)		-0.168		-0.259		-0.00980
		(0.121)		(0.212)		(0.203)
Δln(Import Varieties)		-0.135*		-0.189		-0.196
		(0.069)		(0.126)		(0.125)
HHI		1.671		4.432		4.739
		(1.607)		(2.930)		(3.636)
Observations	14439	14439	14439	14439	14439	14439
R-squared	.001	.008	.001	.006	.002	.004

Notes: ***, **, and * indicate significance at the 1%, 5%, and 10% level. Robust standard errors corrected for clustering at the firm level in parentheses. All regressions include a constant term. Herfindahl index (HHI) is computed in the initial year (2001) at the 4-digit CIC industry in China.