On the Relationship Between Quality and Productivity: Evidence from China's Accession to the WTO*

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Abstract

This paper presents an analysis of the effect of China's entry into the WTO on the quality choices of Chinese exporters in terms of their outputs and their inputs. Using highly disaggregated firm-level data, we show that the quality upgrading made possible by China's tariff reductions was concentrated in the least productive Chinese exporters. These firms, which had been laggards in terms of quality prior to the tariff reduction, were the most aggressive in increasing the quality of their exports and their inputs and in redirecting their exports toward high income markets where demand for high quality goods is strong. Our empirical results are consistent with a simple model in which productivity and quality are complements but in which quality upgrading is subject to diminishing returns. This latter feature does not appear in workhorse models of firm heterogeneity and endogenous quality choice which provide a distorted view of the impact of trade liberalization on quality upgrading.

JEL classification: F12, F14

Keywords: trade liberalization, tariff, export price, productivity, quality upgrading, quality differentiation, product heterogeneity

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1 Introduction

Firms from developing countries historically have failed to break into developed country markets. Much of their difficulties stem from an inability to produce at sufficiently low cost the high quality goods that these markets demand. One of the reasons proposed for the competitive disadvantage of developing country firms is that government efforts to protect domestic intermediate input producers artificially raise the cost of the high quality intermediate inputs necessary to produce high quality goods.

This paper presents an analysis of the effect of China's entry into the WTO on the quality of Chinese exports. We use highly disaggregated firm-product-level data and the shock of China's entry into the WTO to trace through in detail the mechanisms through which trade liberalization contributes to quality upgrading by Chinese firms. We find that the chief beneficiaries of liberalized intermediate input tariffs are not the initially most productive firms but are instead the less productive firms that are operating in industries in which the scope for quality variation is the most pronounced. It is these lower productivity firms that are most likely to upgrade the quality of their exports, increase the quality of their imported intermediates, and upgrade their workforces. In so doing, these firms are better able to break into markets with high demand for product quality and reduce the gap in their quality performance relative to initially more productive firms.

China's entry into the WTO in 2001 provides an excellent opportunity to identify the causal effect of trade liberalization on quality upgrading. First, the tariff reductions imposed on China were largely outside of China's control. Second, China's imports are dominated by intermediate inputs instead of final consumption goods, and so the impact of import tariff reductions is largely operating on imported intermediate inputs.[1] Third, the effect of tariff reductions on the cost of Chinese production is highly heterogeneous across industries and across firms within industries. We carefully calculate total factor productivity of Chinese firms just prior to the trade liberalization and provide the following stylized facts: low TFP exporters were most likely (i) to increase their export prices to foreign destinations, and (ii) to increase the wages they pay their workers and the prices they pay for their inputs. Importantly, these outcomes were only present in those industries in which quality heterogeneity across products is high. Moreover, the evidence at the extensive margin shows that low TFP exporters were most likely to expand into high income country markets where demand for high quality goods is strong.

We develop a simple model of output and input quality choice to flesh out the mechanisms at work. In the model, firms differ in their productivity and maximize profits by choosing the quality of their output and inputs. As in many models of innovation, our model features scale

[1]The universe of Chinese customs data shows that intermediate goods and capital goods account for 74% and 19%, and final goods account for only 4%, of total import values during 2000-2006. A fourth "uncertain" category accounts for approximately 3%. If we view capital goods also as "intermediates", then intermediate goods account for 93% of total imports.

effects whereby a larger market share induces more quality innovation and more productive firms charge higher export prices. Additionally, higher quality output requires higher quality (and more expensive) inputs. More importantly, productivity and low cost inputs are in a sense substitutable. As more productive firms are less affected by cost of inputs, the return to quality upgrading for high productivity firms is less sensitive to tariffs on imported inputs. Consequently, our model makes it possible to explain why more productive firms produce higher quality output using higher quality inputs, but gain less from tariff reductions than less productive firms.

We use the first-order conditions of our model to devise an econometric strategy to estimate the size of mechanism at work in our model. The model's predictions prove to be robust to a wide range of econometric specifications, to alternate methods of calculating tariff reductions enjoyed at the firm level or industry level, and to alternative measures of initial firm productivity. More importantly, we provide support to the interpretation of the data as quality upgrading through input prices of both labor input and imported intermediate inputs. In addition, we present evidence at the extensive margin that the change in export price and destination markets' income is more pronounced for less productive firms who aggressively respond to input tariff reductions by shifting their exports from countries with relatively weak demand for high-quality goods to countries with strong demand for high-quality goods.

Our paper is linked to a large literature on firm heterogeneity in performance. We show how firm heterogeneity in productivity maps into firm heterogeneity in quality and how shocks to the economic environment caused by trade liberalization alters this mapping. Our theoretical model shows and our empirical estimates confirm that the role of productivity is not as simple as the standard heterogeneous-firm models that have followed from the canonical Melitz (2003) framework. In particular, our results show that firms demonstrating high productivity in highly protected developing countries are relatively well adapted for an environment in which high quality intermediates are expensive to procure. In this way, our results provide nuance to the results of Halpern, Koren and Szeidl (2015) who show asymmetric effects across Hungarian firms' measured productivities following a trade liberalization. Improved access to intermediate inputs favors relatively low productivity exporters who were less efficient in handling intermediate inputs before trade.[2]

Our paper also contributes to a growing literature on the impact of greater access to imported intermediate inputs on firm-level performance, especially on export quality.[3] Highly related, recent examples include Fan, Li and Yeaple (2015) and Bas and Strauss-Kahn (2015).

[2]Feng, Li and Swenson (2012) provide evidence that private Chinese firms derived a greater benefit from imported foreign intermediates relative to foreign invested firms, which is consistent with the interpretation given by Halpern, Koren and Szeidl (2015).

[3]For instance, Amiti and Konings (2007) and Kasahara and Rodrigue (2008) for the impact on productivity. Antràs, Fort and Tintelnot (2014) estimate a model in which profits are supermodular in productivity and imports. Goldberg et al. (2010) show that access to greater intermediate inputs induced Indian firms to expand their product scope. Manova and Zhang (2012*a*) focuses on cross sectional data in trying to infer the relationship between export quality and productivity. We take the further step to look at the effect of trade liberalization on the relationship between input/output quality and productivity.

Fan, Li and Yeaple (2015) focus on cross industry heterogeneity. They show that export price increases were present only in those industries in which quality variation was initially high and that firms tended to migrate toward markets and toward products in which quality heterogeneity is most important. Our current paper digs deeper into cross-firm heterogeneity within industries. We show that, both theoretically and empirically, the chief beneficiaries of the tariff reduction with respect to trade liberalization is not the most productive firms who were initially producing relatively high quality goods from high quality inputs but was rather the least productive of the set of exporters. Indeed, the most productive firms may respond little to tariff cuts on their imported intermediates and to the extent that they did, they simply passed cost savings on to consumers. Bas and Strauss-Kahn (2015) explore the link between tariff cuts that hit Chinese exporters asymmetrically and the prices paid by firms for their imported inputs and received for their exports. This paper also differs from Fan, Li and Yeaple (2015) and Bas and Strauss-Kahn (2015) by examining extensive margin effect that firms set different prices for their outputs in different markets and how the extensive margin relates to a firm's initial productivity under trade liberalization.

Much of the literature on the effect of trade liberalization on quality (e.g. Verhoogen, 2008) relies on variation in access to foreign markets following a fall in foreign tariffs or a real exchange rate shock. The interpretation given in these papers tends to be one of scale effects: more productive firms enjoy large sales which tilts innovation decisions toward higher variable profits at the expense of higher fixed costs. Our paper shows this mechanism alone is insufficient to understanding the heterogeneous quality upgrading that is actually observed: the impact on scale effects for the most productive firms needs to be moderated by some form of decreasing variable returns.[4]

The remainder of this paper is organized in five sections. In Section 2, we describe the data and generate a series of stylized facts on the link between firms' initial productivity, export and import prices, and the subsequent adjustment of export and input prices following the trade liberalization. In Section 3, we introduce a model that shows how input and output quality and firm initial efficiency map into a firm's choice of export and input prices and how this mapping is altered by falling input tariffs. In Section 4, we specify a simple econometric model and describe the construction of the data and measures used to estimate the model. Section 5 provides the main results and robustness exercises concerning the link between a firm's initial productivity, the size of the tariff reduction experienced, and the resulting impact on export prices, input prices (such as imported input prices and wage payment) and export destinations. The final section concludes.

[4]Our framework shares much in common with Feenstra and Romalis (2014) who focus primarily on aggregate provision of quality across markets, but do not explore the differential impacts of quality across firms and the heterogeneous response within industry.

2 Data and Stylized Facts

Data.— To capture firms' productivity and import/export prices, we merged two databases: (1) the firm-product-level trade data from Chinese customs, and (2) the firm-level production data, collected and maintained by the National Bureau of Statistics of China (NBSC). Our sample period is between 2001 and 2006.[5]

The transaction-level trade data, provided by China's General Administration of Customs covers the universe of all Chinese exports and imports in 2001-2006 at the HS 8-digit level. For each trade transaction, it records detailed information including import and export values, quantities, products, source or destination countries, contact information of the firm (e.g., company name, telephone, zip code, contact person), type of enterprises (e.g. state owned, domestic private, foreign invested, and joint ventures), and customs regime (e.g. "Processing and Assembling"and "Processing with Imported Materials"). As firms under processing trade regime are not subject to import tariffs, we focus on firms under ordinary trade regime. Then we aggregate transaction-level data to firm-HS6 product-level or firm-HS6-country trade data.[6] For each HS 6-digit product, we use export/import values and quantities to compute unit value export/import prices by each firm.[7] Our empirical analysis for product/variety therefore refers to either HS6 product category or HS6-country combination.

To characterize firms' attributes such as TFP and capital intensity, we also use the NBSC firm-level production data from the annual surveys of Chinese manufacturing firms, covering all state-owned enterprises (SOEs), and non-state-owned enterprises with annual sales of at least 5 million *Renminbi* (RMB). The NBSC database contains firm-level production and accounting information of manufacturing enterprises in China, such as employment, capital stock, gross output, value added, and firm identification (e.g., company name, telephone number, zip code, contact person). Due to some mis-reporting, we follow Cai and Liu, 2009 and use General Accepted Accounting Principles to delete the unsatisfactory observations.[8]

Then we merge the firm-product-level trade data from the Chinese Customs Database with the NBSC Database using the contact information of manufacturing firms.[9] Our matching

[5]We do not include the year 2000 because the WTO tariff data at HS 8-digit level are not available.

[6]China changed HS-8 codes in 2002, and the concordance between the old and new HS-8 codes (before and after 2002) is not available. To ensure the consistency of the product categorization over time (2001-2006), we choose to adopt HS-6 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.

[7]We use two measures to compute unit value export/import prices: (1) the export/import prices of each HS 6-digit goods by each firm, and (2) the export/import prices of the HS 6-digit goods shipped to/from different countries by each firm, i.e., we view the same HS 6-digit goods exported to/imported from different countries as "different" varieties.

[8]We use the following rules to construct our sample: (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 must have a unique identification number; and (v) the established time must be valid.

[9]This merging has to be done using the contact information of firms due to the lack of consistent firm identification between the two databases. The NBSC Database uses the corporate representative codes to identify firms while the Customs Database adopts another set of corporate custom codes as firm identity.

procedure is done by company name first, and next by both zip code and telephone number, and lastly by telephone number and contact person name together (see detailed description of the matching process in Fan, Lai and Li, 2015). Compared with the exporting and importing firms 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.[10]

We use the NBSC firm-level production data to measure revenue TFP in our main results. To overcome known issues in revenue TFP, we also show that our main results are robust to physical TFP measures by merging the firm-level revenue-based production data with another newly obtained dataset on firms' quantity output from the NBSC for the same sample period (see Section 4.3 for more detailed discussion on various TFP measures and their estimation methods).[11]

Finally, the Chinese import tariff data are obtained from the WTO website, available as MFN (most-favored nation) applied tariff at the most disaggregated level, the HS 8-digit level, for the period 2001-2006.[12] As our product is defined at HS6 level, we compute average tariff at HS6 level by using each HS8 tariff line within the same HS6 code. We then calculate firm-specific and industry-specific tariffs in empirical investigation (see more details in Section 4.2). The summary statistics of key variables in our firm-product(-country) sample for regression analysis are reported in Table 1.

Stylized Facts.— Now we document three stylized facts concerning the relationship between output/input prices and productivity during trade liberalization using unit-value price as proxy for quality.[13] The key message from those facts is the closing gap between less and more productive firms following the initial differences in terms of their output and input prices under trade liberalization. As China joined the WTO in December of 2001, we use the data from 2001 to represent the pre-liberalization period and data from 2006 to represent the post-liberalization period. All firms we examine are incumbent exporting/importing firms that are present in both pre- and post-liberalization periods. Since a product is defined at either HS6 or HS6-destination level, it is convenient to compare the changes in export prices at different levels of aggregation that can uncover how changes in the composition of destination markets affect average export prices.

Fact 1: Export prices and price changes.— Table 2 reports the changes in (log) export prices by less and more productive firms via the levels of export prices in both 2001 and 2006.

These two firm identity coding systems are not transferable between each other.

[10]When merging the Customs Database with the NBSC data, we exclude intermediaries and/or trading companies.

[11]This quantity output database contains information on each product, defined by the Chinese product classification (CPC) at the 5-digit level, produced by the firm, and in particular, output quantity. We are able to merge this quantity database with the NBSC production data as the two databases adopt the same firm identification code. We will focus on single-product firms in estimating physical TFP.

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

[13]Using unit-values as proxy for quality is a usual practice in the literature since the observed differences in unit-values are mainly attributed to quality (Feenstra and Romalis, 2014).

Table 1: Summary Statistics of Key Variables and Sample

Variable	Mean	Median	S.D.	Min	Max
Sample: Firm-HS6-country					
$\Delta\ln(\text{price})$	0.13	0.09	0.90	-7.64	9.94
ΔDuty	-0.06	-0.05	0.05	-1.11	0
$\Delta\ln(\text{TFP})$	0.43	0.38	0.95	-9.08	5.76
$\ln(\text{price})_{2001}$	1.51	1.26	2.18	-9.07	12.76
$\ln(\text{price})_{2006}$	1.63	1.38	2.16	-6.54	12.49
$\ln(\text{TFP})_{2001}$	4.34	4.30	1.05	-0.62	8.36
$\ln(\text{TFP})_{2006}$	4.77	4.78	1.10	-5.41	8.53
Sample: Firm-HS6					
$\Delta\ln(\text{price})$	0.15	0.11	1.01	-9.26	9.96
ΔDuty	-0.06	-0.06	0.05	-1.11	0
$\Delta\ln(\text{TFP})$	0.42	0.36	0.97	-9.08	7.35
$\ln(\text{price})_{2001}$	1.53	1.30	2.08	-9.07	13.27
$\ln(\text{price})_{2006}$	1.68	1.45	2.05	-7.55	14.20
$\ln(\text{TFP})_{2001}$	4.26	4.25	1.05	-0.62	8.36
$\ln(\text{TFP})_{2006}$	4.68	4.67	1.10	-5.41	8.53

Notes: The summary statistics of key variables for the continuing firm-HS6-country triplets are reported in the top panel. The number of continuing firm-HS6-country combinations is 16907 and the number of correspondent firms is 2600. The summary statistics of key variables for the continuing firm-HS6 combinations are reported in the bottom panel. The number of continuing firm-HS6 combination is 8971 and the number of correspondent firms is 2889. Key variables is consist of (log) price and TFP at year 2001 and 2006, their log change from 2001 to 2006 as well as firm-specific tariff reduction.

Firms are divided into two groups – high- and low-productivity firms based on whether their labor productivity (value added per worker) is above or below the median in the pooled sample in 2001.[14] Within each group, the median and mean (log) export prices per firm-product in 2001 and in 2006 as well as the percentage changes (in parentheses) are reported.

Table 2: Export Prices in 2001 and 2006 and Price Changes from 2001 to 2006

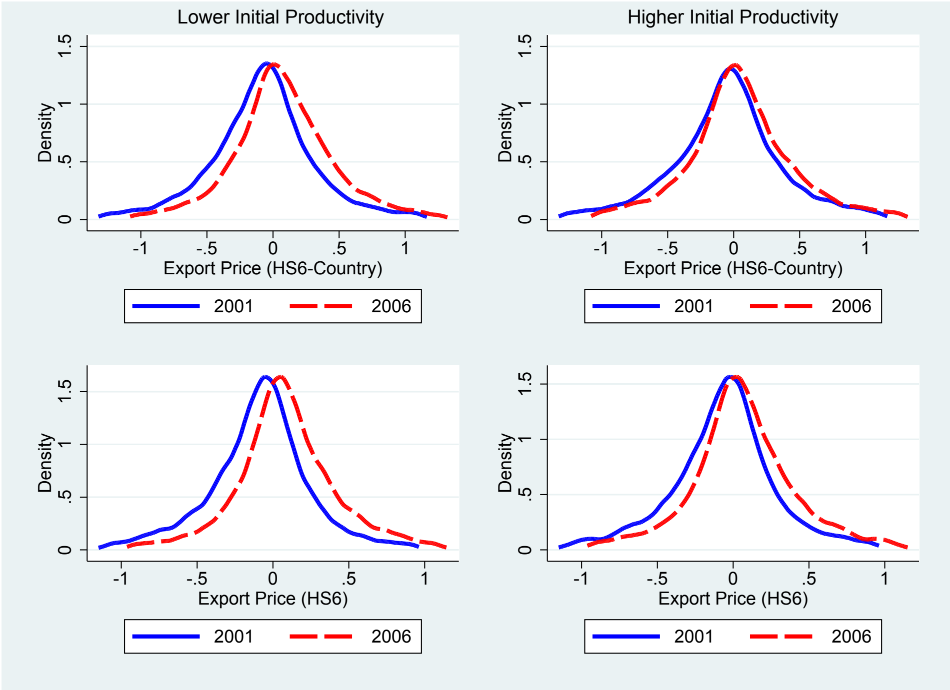
	Firm productivity $\leq$50th (in 2001)		Firm productivity >50th (in 2001)	
	(1)	(2)	(3)	(4)
	2001	2006	2001	2006
Export Price (HS6-County)				
Per Firm-product-country, median	1.04	1.22 (17.68%)	1.33	1.38 (5.00%)
Per Firm-product-country, mean	1.11	1.28 (17.54%)	1.59	1.68 (9.06%)
Export Price (HS6)				
Per Firm-product, median	1.13	1.33 (20.40%)	1.38	1.51 (12.66%)
Per Firm-product, mean	1.18	1.37 (19.65%)	1.64	1.75 (11.78%)

Notes: Prices are in logarithm. Export prices are unit values, computed by dividing deflated export values by the physical quantity. Price changes are presented in parentheses.

Table 2 shows that firms with lower initial productivity increase export prices more than

[14] Using estimated total factor productivity (TFP) to group the data yields similar patterns.

Figure 1: Distributions of Export Prices by Initial Firm Productivity in 2001 and 2006



Notes: Prices for continuing firm-HS6-country triplets (see the top panel) and for continuing firm-HS6 combinations (see bottom panel) are in logarithm. Graphs in the left panel refer to firms with lower initial productivity (i.e., productivity lower than the median) and graphs in the right panel refer to firms with higher initial productivity (i.e., productivity above the median). Price distributions are drawn by regressing export prices on firm-HS6-country (see the top panel) and firm-HS6 (see the bottom panel) fixed effects and then plotting the residuals, as in De Loecker et al. (forthcoming).

those with higher initial productivity, at both firm-product and firm-product-country levels. It is also interesting to note that the price increases are greater at HS6 product level than at HS6-country level due to a composition effect, i.e., firms would charge higher average export prices by entering more destination markets where demand for high quality goods is strong after trade liberalization. To better illustrate the difference between low- and high-productivity firms regarding the change in their export prices of both HS6-country or HS6 products, we also plot the distributions of export prices (in natural logarithm) in 2001 and 2006 in Figure 1. The left panel of Figure 1 refers to firms with initial productivity lower than median productivity; the right panel refers to firms with productivity higher than the median. In the two graphs in the top we include firm-HS6-country triplets that are present in both years for the distribution of prices, while in the two graphs in the bottom we focus on firm-HS6 products. Then we compare export prices over time by regressing them on firm-HS6(-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, and this shifting pattern is more profound for low-productivity firms. We summarize the first stylized fact as follows:

Stylized fact 1. *During trade liberalization, firms with lower initial productivity raise export* *prices more than those with higher initial productivity.*

Table 3: Change in Export Prices vs. Initial Productivity

	Whole Sample		Differentiated goods		Homogeneous goods	
	(1)	(2)	(3)	(4)	(5)	(6)
	≤50th	>50th	≤50th	>50th	≤50th	>50th
Change in Export Price (HS6-Country):						
Per Firm-product-country, median	11.93%	5.86%	13.23%	7.24%	0.34%	-0.16%
Per Firm-product-country, mean	17.53%	9.05%	18.67%	10.35%	0.81%	0.95%
Change in Export Price (HS6):						
Per Firm-product, median	14.48%	8.92%	16.12%	11.56%	1.16%	-2.74%
Per Firm-product, mean	19.65%	11.78%	20.96%	13.45%	5.39%	2.33%

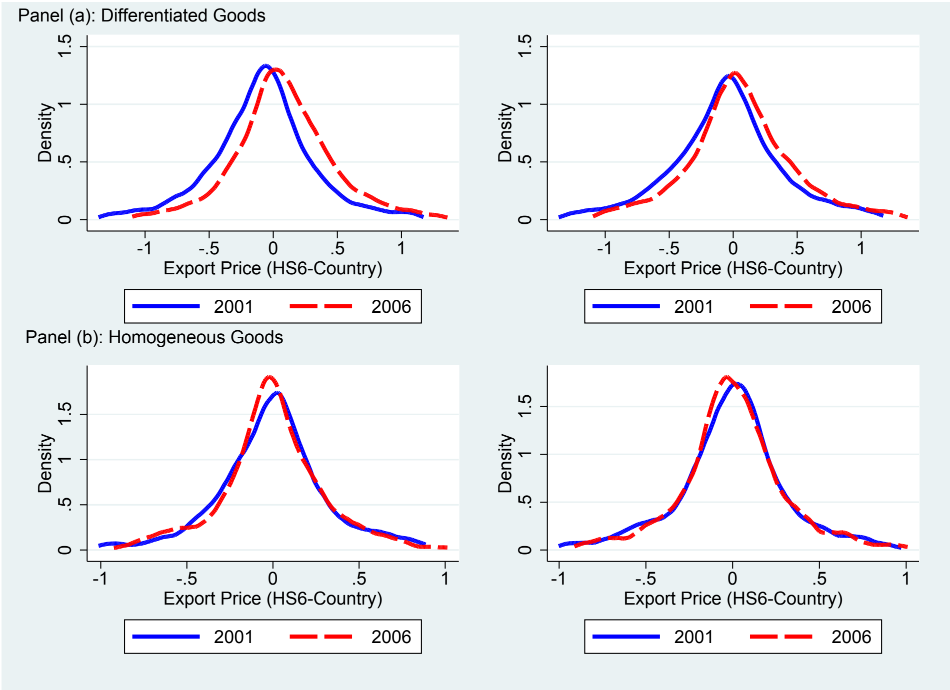
Notes: ≤50th indicates the firms associated with lower initial productivity (i.e., the bottom 50th percentile); >50th indicates the firms associated with higher initial productivity (i.e., the top 50th percentile).

Fact 2: Heterogeneity across industries.— To explore whether the effect of trade liberalization on export prices depends on quality 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 (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 3 conveys two messages: First, for differentiated products, the firms with lower initial productivity always raise their export prices more than those with higher initial productivity (see column 1 vs. 2), while for homogeneous goods the difference between price changes of firms with different productivity are less pronounced (see column 3 vs. 4). Second, the price changes of differentiated goods are significantly larger than those of homogeneous goods within the firms with similar productivity. Figure 2 also presents the differential effect of product differentiation on price distributions by firm productivity: the export prices of differentiated goods significantly increase from 2001 to 2006 (see Panel (a)) but the firms with lower initial productivity increase export prices by more (see the left graph in Panel (a)); while the export prices of homogeneous goods nearly remain unchanged over time (see Panel (b)).[15] This suggests that the effect of tariff reduction on export prices depends on the scope for product differentiation, and the changes in export prices conditional on firms' different levels of initial productivity are also consistent with this rule. The result is summarized as the following finding:

Stylized fact 2. *During trade liberalization, firms with lower initial productivity raise export prices of heterogeneous-quality products more than those with higher initial productivity, while the difference between the changes in export prices of homogeneous-quality products for firms with different productivity levels are less pronounced.*

[15] Figure 2 is based on HS6-country products. We also present the distributions of export prices for HS6 products in Figure A.1 in Appendix A and the pattern is similar.

Figure 2: Distributions of Export Prices by Initial Productivity and Product Heterogeneity (HS6-country)



Notes: Prices for continuing firm-HS6-country triplets are in logarithm. The three graphs in the top panel refer to firms with lower initial productivity (i.e., productivity lower than the median) and the three graphs in the bottom panel refer to firms with higher initial productivity (i.e., productivity above the median). Price distributions are drawn by regressing export prices on firm-HS6-country fixed effects and then plotting the residuals, as in De Loecker et al. (forthcoming). The two graphs in the right panel refer to whole sample, the two graphs in the middle panel refer to differentiated goods, and the two graphs in the bottom panel refer to homogeneous goods.

Table 4: Changes in Wages & Import Prices from 2001 to 2006 and Their Initial Values

	(1) ≤50th	(2) >50th	(3) ≤50th	(4) >50th	(5) ≤50th	(6) >50th
	Change in Wage Payment (Firm Level) Per Firm		Change in Import Price (HS6-Country Level) Per Firm-HS6-Country		Change in Import Price (HS6 Level) Per Firm-HS6	
Median	32.34%	23.61%	10.54%	6.92%	12.63%	6.26%
	[1.91]	[2.24]	[2.65]	[3.08]	[2.62]	[3.11]
Mean	40.38%	27.55%	19.54%	13.43%	23.41%	15.20%
	[1.80]	[2.22]	[2.94]	[3.21]	[2.93]	[3.30]

Notes: The initial values (in logarithm) refer to wage payment and import prices in 2001 (presented in brackets underneath). ≤50th indicates the firms associated with lower initial productivity (i.e., the bottom 50th percentile); >50th indicates the firms associated with higher initial productivity (i.e., the top 50th percentile).

Fact 3: Changes in input prices.— Table 4 shows that the changes in labor input prices through wage payment per firm and the percentage changes in import prices for intermediate inputs per firm-product between 2001 and 2006 indeed depend on initial firm productivity. Columns 1 and 2 present the results for wage payments; columns 3-4 and 5-6 show the results for import prices at HS6-source country and HS6 level, respectively. Table 4 clearly shows that the increases in wages and import prices are greater for initially low productivity firms (see the odd columns vs. even columns). Also, the initial values in brackets show that more productive firms pay higher input prices at the beginning. Hence, we have the following stylized fact:

Stylized fact 3. *More productive firms pay higher input prices for both its primary and intermediate inputs. During trade liberalization, firms purchase more expensive labor and intermediate inputs. This effect is more pronounced for less productive firms.*

3 Model

The stylized facts shown in the previous section present a challenge for existing theory. On the one hand, the positive relationship between input and output and firm productivity for a given level of intermediate input tariffs is consistent with standard scale effects in which quality upgrading requires significant overhead costs. On the other hand, the fact that a reduction in input tariffs weakens this link is inconsistent with standard theory. In this section, we show that a form of decreasing returns to productivity can generate the apparent substitution of cheaper high quality inputs and firm productivity.

3.1 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.

Producing a higher quality product raises firm profitability directly through its affect on demand but it is more costly to the firm for two reasons. First, 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.

Second, producing higher quality output requires firms to use higher quality inputs. The production function for output of quality q for a firm of productivity φ takes the following form:

$$x_i(q) = \varphi \left(\frac{V(q)}{1-\mu_i} \right)^{1-\mu_i} \left(\frac{M_i(q)}{\mu_i} \right)^{\mu_i}, \ \mu_i \in (0,1) \tag{2}$$

where $V(q)$ is a bundle of primary factors of quality q, $M_i(q)$ is a composite intermediate input of quality q that is used in industry i, and φ is firm productivity. The price facing the firm for a bundle of primary factors of quality q is given by $w(q) = wg(q)$, where $g(q)$ is a strictly increasing function of quality. The price of a bundle of intermediate inputs of quality q is given by $P_{iM}(q)$. The composite intermediate input is produced via a Leontief production function over a unit interval of individual intermediates, indexed by $m \in [0,1]$. The price of any input m of quality q in China is $p_d g(q)$, where p_d is a constant. A firm may also source an intermediate input from abroad. The imported price of that intermediate input m of quality q is $\tau p_f(m) g(q)$, where τ is one plus the ad valorem tariff on the input and $p_f(m)$ is strictly decreasing and continuous in m.[16] We assume that $\tau p_f(0) > p_d$ and $\tau p_f(1) < p_d$ so that there exists a cutoff intermediate that is not imported that is solution to

$$\tau p_f(m^*) = p_d.$$

Hence, the price of the composite intermediate input of quality q is given by

$$P_{iM}(q;\tau) = \widetilde{P}_{iM}(\tau) g(q), \ \text{where } \widetilde{P}_{iM}(\tau) = \left(m^* p_d + \tau \int_{m^*}^{1} p_f(m) dm \right). \tag{3}$$

It follows from these assumptions, that the cost of production of a firm of productivity φ for a level of quality q is given by

$$c_P(q;\varphi,\tau) = \frac{w^{1-\mu_i} \left(\widetilde{P}_{iM}(\tau) \right)^{\mu_i}}{\varphi} g(q). \tag{4}$$

In addition to production costs, firms also face a variety of additional costs of distribution

[16] In Appendix B, we develop a simple microfoundation for the price setting given here.

and handling of their output. Higher quality goods require better after-production services given by $S(q) = swg(q)$. We assume that these costs are per unit of output sold so that the total cost of providing a unit of final output to its final consumers is given by

$$C_i(q;\varphi,\tau) = \left(sw + \frac{w^{1-\mu_i}\left(\widetilde{P}_{iM}(\tau)\right)^{\mu_i}}{\varphi} \right) g(q). \tag{5}$$

Henceforth, we parameterize the quality premium schedule as $g(q) = q^{\alpha}$.[17]

3.2 Implications

We now explore the implications of our model for firms' choices of quality of inputs, outputs, and prices as a function of firms' productivities and the input tariffs that they face. We consider a particular industry and drop the industry subscript i, henceforth.

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

$$\pi(\varphi) = \max_{p,q} \left((p - C(q;\varphi,\tau))\, x(q,p,\omega) - fq^{\beta} \right),$$

Substituting using (1) and (5) and solving for the first-order conditions for the choice of quality of outputs and inputs and the price of the final good, we find that the optimal quality choice is given by

$$q = \left((\eta - \alpha(\sigma-1)) \frac{A}{\beta f} \left(sw + \frac{w^{1-\mu}\left(\widetilde{P}_{M}(\tau)\right)^{\mu}}{\varphi} \right)^{1-\sigma} \right)^{\frac{1}{\beta-\eta+\alpha(\sigma-1)}}, \tag{6}$$

where $A = \frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \nu E P^{\sigma-1}$ is the mark-up adjusted demand level common to all firms in the same industry, and the optimal price is given by

$$p = \frac{\sigma}{\sigma-1} \left((\eta - \alpha(\sigma-1)) \frac{A}{\beta f} \right)^{\frac{\alpha}{\beta-\eta+\alpha(\sigma-1)}} \left(sw + \frac{w^{1-\mu}\left(\widetilde{P}_{M}(\tau)\right)^{\mu}}{\varphi} \right)^{\frac{\beta-\eta}{\beta-\eta+\alpha(\sigma-1)}}. \tag{7}$$

Note that an interior solution requires that $\beta > \eta - \alpha(\sigma-1) > 0$, which we assume holds henceforth.

We first consider the variation across firms in their choices of the quality of inputs, outputs and price as a function of variation across firms in their productivities given a tariff on

[17] The assumption that after production services vary in quality is realistic but is made primarily for convenience. The key implications below do not require this service to vary in quality.

intermediate inputs. Differentiating equations (6) and (7), yield the elasticities of quality and output price with respect to firm productivity. This yields after substitution,

$$\frac{dq}{q} = \frac{\sigma-1}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{d\varphi}{\varphi}, \text{ and} \tag{8}$$

$$\frac{dp}{p} = \frac{\eta-\beta}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{d\varphi}{\varphi}. \tag{9}$$

Given that an increase in quality of output implies an increase in the quality of inputs, the following propostion is immediate from equations (8) and (9):

Proposition 1. *More productive firms always produce higher quality output than less productive firms and so use inputs (local and foreign) that feature higher prices than less productive firms. In industries in which the scope for quality differentiation is high ($\eta > \beta$), more productive firms also charge higher prices for their output than less productive firms while the opposite is true in industries in which the scope for quality differentiation is small ($\eta < \beta$).*

The prediction is consistent with the stylized fact that more productive firms pay higher wages and buy higher quality inputs. We now consider the effect of a reduction in the tariff on intermediate inputs such as followed China's accession to the WTO. Totally differentiating equations (6) and (7), we obtain

$$\frac{dq}{q} = -\frac{\mu\,(\sigma-1)}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{\tau\int_{m^*}^{1}p_f(m)dm}{\int_0^{m^*}p_d dm+\tau\int_{m^*}^{1}p_f(m)dm}\frac{d\tau}{\tau} \tag{10}$$

$$\frac{dp}{p} = -\frac{\mu\,(\eta-\beta)}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{\tau\int_{m^*}^{1}p_f(m)dm}{\int_0^{m^*}p_d dm+\tau\int_{m^*}^{1}p_f(m)dm}\frac{d\tau}{\tau}. \tag{11}$$

The following propositions are immediate from equations (10) and (11):

Proposition 2. *A reduction in tariffs on intermediate inputs induces firms to upgrade their quality. This effect is smaller in absolute magnitude for high productivity firms. The differential effect between low- vs. high-productivity is most pronounced in industries in which the scope for quality differentiation is higher (high η or small β).*

Proposition 3. *In industries in which the scope for quality differentiation is high ($\eta > \beta$), a reduction in tariffs on intermediate inputs induces firms with lower productivity to raise the price of their final output more than those with higher productivity. The differential effect between low- vs. high-productivity is most pronounced in industries in which the scope for* *quality differentiation is higher (high η or small β); while the opposite is true in industries in which the scope for quality differentiation is small ($\eta < \beta$).*

The above propositions are consistent with Fan, Li and Yeaple (2015), but extend the implications to the differential effect between low- vs. high-productivity and to the choice of input qualities. Now, the impact of the tariff reduction on the payment for both primary factors and foreign intermediate inputs satisfy

$$\frac{dw(q)}{w(q)} = -\frac{\mu\alpha\,(\sigma-1)}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{\tau\int_{m^*}^{1}p_f(m)dm}{\int_0^{m^*}p_d dm+\tau\int_{m^*}^{1}p_f(m)dm}\frac{d\tau}{\tau} \tag{12}$$

$$\frac{d\left[p_f(m)g(q)\right]}{p_f(m)g(q)} = -\frac{\mu\alpha\,(\sigma-1)}{\beta-\eta+\alpha(\sigma-1)}\frac{\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}{s\varphi+\left(\widetilde{P}_M(\tau)/w\right)^{\mu}}\frac{\tau\int_{m^*}^{1}p_f(m)dm}{\int_0^{m^*}p_d dm+\tau\int_{m^*}^{1}p_f(m)dm}\frac{d\tau}{\tau} \tag{13}$$

Upgrading of input qualities, induced by a reduction in tariff on intermediate inputs, increases the payment for primary factors.

Proposition 4. *A reduction in tariffs on intermediate inputs, τ, induces firms with lower productivity to increase the payment for both its primary and intermediate inputs more than those with higher productivity. The differential effect between low- vs. high-productivity is most pronounced in industries in which the scope for quality differentiation is higher (high η or small β).*

The prediction of the model that more productive firms produce higher quality and sell at higher prices but respond less to a reduction in the cost of imported intermediates is novel to this model. That more productive firms produce higher quality and sell at higher prices in any given environment is driven by the scale effects associated with increasing fixed costs of quality. The blunted impact of tariff reductions is due to the fact that productivity and low cost inputs are in a sense substitutable so that a reduction in tariffs on intermediate inputs has a bigger impact on the costs of less productive firms. Hence, these two mechanisms are sufficient to generate the empirical regularities observed in the data.

Before concluding this section, we describe a simple extension of the model that would allow analysis of the extensive margin. By observation of equation (6), it is immediate that firms sell higher quality products in countries with high demand, A, which in some extent reflects GDP per capita since higher quality products are consumed in these countries. Suppose that countries with high levels of demand (A) involve very high upfront investments in distribution and advertizing. If these investments are sufficiently costly, only the most productive firms would sell there. As a reduction in input tariffs lowers the variable costs of less productive by a larger percentage, it is the less productive firms that are most likely to upgrade the set of markets in which they operate. Specifically, those less productive firms will start exporting to countries with higher demand A and, as a result, to raise export prices more, since more productive firms have already been operating in those higher demand markets before trade liberalization. We will show below that this is exactly what happens in the data.

In summary, we have shown that understanding the data require the standard model regarding the relationship between quality upgrading and firm productivity to be amended in such a way that low input prices and firm productivity are substitutes. Moreover, the model makes predictions over the logarithmic changes in tariffs to logarithmic changes in the price of inputs and the price of outputs at the firm level where the effect of tariff changes is heterogeneous across firms of different initial productivities. In the next section, we devise a simple econometric model that captures exactly these predictions.

4 Empirical Strategy

In this section we specify our main estimating equation and describe the measures of the key components of the econometric model, namely, tariff reductions and productivity.

4.1 Baseline Specification

Our empirical investigation is guided by the propositions of our model regarding the changes in output and input prices with respect to firm productivity during trade liberalization. To test how the effect of tariff reductions on export prices depends on firm productivity, we estimate the following equation:

$$\Delta \ln(p_{fh(c)}) = \beta_1 \Delta Duty_f + \beta_2 \Delta Duty_f \times \ln(TFP)_f + \beta_3 \Delta \ln(TFP)_f + \boldsymbol{\beta}_f \Delta \boldsymbol{\chi}_f + \beta_i \Delta HHI_i + \varphi_s + \epsilon_{fh(c)}, \tag{14}$$

where Δ denotes a change in any variable during a five-year period between 2001 and 2006, i.e, $\Delta x = x_{2006} - x_{2001}$;[18] $\Delta \ln(p_{fh(c)})$ denotes the change in log unit value export price of HS6 product h exported by firm f to destination country c. The specification can represent a firm-product-destination-level (fhc) regression or one at the firm-product level (fh), in which case the optional c subscript is omitted. $\Delta Duty_f$ is the change of import tariff faced by firm f which is firm-specific (see detailed description on the construction of firm-specific tariff measures in Section 4.2);[19] $\Delta Duty_f \times \ln(TFP)_f$ is the interaction term of the change of import tariffs and the firm's initial productivity; $\Delta \ln(TFP)_f$ controls for the change in

[18] We use long difference because the adjustment to the shock of trade liberalization may be slow (e.g., Fan, Li and Yeaple, 2015) and there may also be issues of autocorrelation when estimating the model in levels (Trefler, 2004). We also experiment with shorter difference estimators using various periods, including four-year, three-year, and two-year difference. The results remain qualitatively similar and are reported in Table A.9 in Appendix D.

[19] We also report results using conventional industry-level input tariffs in robustness checks (see Section 5.1.2) and obtain qualitatively similar results.

firm productivity (estimated TFP) that affects price change.[20] The vector $\Delta\boldsymbol{\chi}_{ft}$ consists of other firm-level observables that potentially affect export prices, including the change of capital intensity (capital to labor ratio), the change of total employment, and the change of total wage bill. We also add ΔHHI_i to control for the change in competition effect through Herfindahl index, computed at the 4-digit CIC (Chinese Industrial Classification) industry level. In addition, we control the 2-digit CIC industry-fixed effect φ_s. Finally, $\epsilon_{fh(c)}$ is unobserved demand and cost shocks that affect export prices. When we examine input prices, the dependent variable will be replaced by import prices at firm-HS6(-country) level or wage payments at firm level.

Our theory predicts that the coefficient of $\Delta Duty_f$, β_1 and, in particular, the coefficient of the interaction term $\Delta Duty_f \times \ln(TFP)_f$, β_2, should be negative and positive, respectively in the industries where the scope for quality differentiation is large. As the scope for quality differentiation decreases, the aforementioned effect becomes weaker, i.e., β_1 increases and even becomes positive, β_2 decreases and may also becomes negative such that the differential effects of tariff reduction on price change for low productivity and high productivity firms would attenuate or even reverse. We now turn to the construction of the variables used to estimate (14).

4.2 Tariff

As the main focus of this paper is to explore the relationship between prices and productivity under trade liberalization, it is important to measure properly the effective tariff reductions that are actually faced by firms. As in Fan, Li and Yeaple (2015), we focus on firm-specific measures of tariff reductions due to their consistency with our theory: those firm-specific measures use information on the exact initial bundle of intermediates imported by firms employing heterogeneous technologies and provide high resolution to the firm-specific intensive margin effects of tariff reduction within the same industry.[21] In robustness checks we also construct conventional industry-level input-output table based measures that would be more comprehensive in capturing the potential to import more intermediates if firms obtain some of the foreign intermediate inputs from other importing firms, but may miss much of the variation of the impact of tariff reductions across firms within the same industry. Our empirical results are not sensitive to alternative measures of tariff cuts.

Our main measure of firm-specific tariff reduction is $\Delta Duty_f = \sum_{h \in Z} w_h \Delta Duty_h$, where the weight w_h is the import share of product h in the total import value by the firm in

[20] In an alternative specification, we experimented with including initial TFP level (rather than the change in TFP) along with other initial firm and industry characteristics, and obtain largely similar results.

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

the initial year, and $\Delta Duty_h$ is the tariff change at HS6 product level.[22] This firm-specific input tariff reduction measure reflects changes in effective tariffs faced by each firm and is not subject to the problem of the weight change from 2001 to 2006.

To assess robustness, we adopt three alternative firm-specific measures of tariff reductions. The first is the arithmetic mean of product-level tariff reductions across all imported varieties both before and after the trade liberalization. The formulation is $\Delta Duty_f = \left(\sum_{h \in Z \cup Z'} \Delta Duty_h\right) / |Z \cup Z'|$, where Z is the set of varieties imported before the tariff reduction (intensive margin), Z' is the set of newly imported varieties after the tariff reduction (extensive margin), and $|Z \cup Z'|$ denotes the total number of imported varieties by the firm over the whole sample period. This measure includes tariff changes relevant to both the intensive margin and the extensive margin.[23] The second measure is the weighted average tariff reductions only to goods that are clearly intermediate inputs, according to the Broad Economic Categories (BEC) classification.

The third measure attempts to connect individual tariff reductions on intermediate inputs to specific goods in the firm's export portfolio of products. We follow Manova and Zhang (2012*b*) to focus on foreign inputs in the same broad industry classification as the output product. For example, if a firm buys brakes and seat belts and sells cars, both its exports and imports would be recorded in the motor vehicles industry. 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, we construct the weighted average tariff change across all the inputs imported by the firm (e.g. brakes, seat belts) in a given HS2 category (e.g. motor vehicle) and assign this average tariff change to all products exported by this firm in the same HS2 category. Using this method we eventually compute the firm-product specific tariff change $\Delta Duty_{fh}$ for each product h exported by firm f.[24] Among all the 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.

4.3 Productivity

To control for the change in firm productivity, we estimate various measures of productivity, including revenue-based total factor productivity (TFP), physical TFP, and value added per worker. We also report results using firm size and alternative quantity-based proxy for firm-product level productivity. Our results are robust to these alternative productivity measures.

[22] $\Delta Duty_h \approx \Delta \ln \tau_h$ since $\tau > 1$ is one plus the tariff rate, and the HS6 product index h is the empirical counterpart of intermediate type z in the model. As in Fan, Li and Yeaple (2015), we use only the import shares as weights because we lack data on domestic intermediate use.

[23] This measure isolates pure changes in tariffs rather than the changes in input bundles (Ge, Lai and Zhu, 2011) by fixing the total number of imported varieties over the sample period.

[24] When we use this firm-product specific tariff measure, we cluster standard errors at firm-product level instead of firm level. 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 results are available upon request.

Our primary TFP measure is revenue TFP using the augmented Olley-Pakes (hereafter O-P) method (Olley and Pakes, 1996). The augmentation takes into account a number of additional firm level decisions. For instance, we allow a firm's trade status in the TFP realization, as in Amiti and Konings (2007), by including 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). We also include a WTO dummy (i.e., one for a year since 2002 and zero for before) in the O-P estimation as the accession to WTO represents a positive demand shock for China's exports.

In estimating revenue TFP, we use value-added to measure production output,[25] and deflate firms' inputs (e.g., capital) and value added, using the input price deflators and output price deflators from Brandt, Van Biesebroeck and Zhang (2012).[26] 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 measure the depreciation rate, we use each firm's real depreciation rate provided by the NBSC firm-production database. Besides TFP estimated using the O-P method, our results are robust to various approaches in estimating revenue TFP, including the OLS method and the Ackerberg-Caves-Frazer augmented O-P and L-P (Levinsohn and Petrin, 2003) methods (Ackerberg, Caves and Frazer, 2006).

We acknowledge that estimating revenue TFP when output is replaced by sales or value added deflated by industry-wise producer price index may pollute the measure with price variation across firms. To resolve this problem, we also report results using physical TFP, firm-product export quantity as proxy for firm-product-level productivity, and other variables of efficiency or firm size, such as value added per worker, total sales or total employment payment. To estimate physical TFP, we follow the method by De Loecker et al. (forthcoming) and merge the NBSC firm-level production data with another newly obtained dataset on firms' quantity output (see Appendix C for more detailed discussion on estimation approach of physical TFP). Due to the data limitation, we can only focus on the single-product firms. As a result, the sample for physical TFP is about 25% of our previous sample for revenue TFP since we use single-product firms.[27] To control for omitted firm-specific input prices, we use the (unit value) output prices, market shares and export status to replace the input prices in estimating the quantity-based TFP.[28] Those results will be reported in "Robustness for Main Results" in Section 5.1.2 and are qualitatively similar to those results obtained using revenue TFP.

[25] Our results are not sensitive to TFP measures estimated by total output with material input. The results are available upon request.

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

[27] Nevertheless, the estimated physical TFP and revenue TFP is positively correlated. The correlation between revenue-based TFP and quantity-based TFP in our sample is 26.41%.

[28] Here output prices refer to unit value prices of each CPC product for single-product firms, calculated by the ratio of sales income to output quantity of CPC product for each firm. Even if we would not control for input prices, we still need to control for output prices of each firm since output prices would affect the consumer's demand.

5 Results

In this section, we present the results of our empirical analyses. We begin with firm-level export price responses to tariff reduction. After presenting the baseline results and robustness checks, we then consider firm-level input price responses to tariff reduction. We conclude the section with evidence regarding firm-level extensive margin responses.

5.1 Export Prices and Import Tariffs

5.1.1 Main Results

We report the impact of tariff reductions on export price changes in Table 5 using the baseline regression equation (14) with firm-product-country level price changes (see columns 1-3) and firm-product level price changes (see columns 4-6) as dependent variable.

We first discuss the results at firm-product-country level. Column 1 reports the coefficient estimate of regression of log changes in export prices on log changes in tariff reductions. The statistically significant and negative coefficient on tariff changes indicates that a reduction in import tariffs of 10 percentage points *increases* unit value export prices at firm-product-country level by 3.4%. This result is consistent with Proposition 3 that tariff reductions induce an incumbent importer/exporter to raise its output prices. In columns 2 and 3, we add the interaction term of tariff change and initial productivity (ΔDuty$\times$log(TFP)), without and with firm- and industry-level controls and industry fixed effect, respectively. The positive, and statistically significant coefficients on the interaction term of tariff change and initial productivity suggest that initially less productive firms enjoy a larger raise in export prices during trade liberalization. Specifically, for the average firm with the mean $ln(TFP) = 4.3$, a 10% reduction in import tariffs raises export prices by approximately 3.5% in columns 2-3, while a 10% less productive firm (compared with the average firm) would increase its export price by 5.7% under the same 10% reduction in import tariffs, which 62.9% greater for this less productive firm than the average firm. This result confirms the second finding in Proposition 3 that the magnitude of the effect of tariff reductions on export prices is decreasing in a firm's productivity.

When we move to columns 4-6 for firm-HS6 product level regressions, similar results obtain: a reduction in import tariff induces firms to increase export prices, and this effect is more pronounced for low-productivity firms.[29] The fact that the coefficient estimates on tariffs and interaction terms tend to be larger at the firm-HS6 level than at the firm-HS6-country level suggests a composition effect: import tariff reductions induce Chinese firms to export to markets with strong demand for higher quality goods where higher prices can be

[29] We also run an F-test on key results for tariff and its interaction with TFP, since there exists a certain amount of collinearity, especially when coefficients are not independently significant. The results show that both coefficients of interest are statistically significant, at at least 1 percent significance level.

Table 5: Baseline Results: Effects of Tariff Reductions on Export Prices Depend on TFP

	Dependent Variable: $\Delta\ln(price)$					
	$\Delta\ln(p_{fhc})$			$\Delta\ln(p_{fh})$		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-0.343*	-2.496***	-2.457***	-0.543**	-3.455***	-3.084***
	(0.191)	(0.654)	(0.702)	(0.234)	(0.869)	(0.930)
ΔDuty×ln(TFP)		0.490***	0.505***		0.652***	0.592***
		(0.139)	(0.150)		(0.188)	(0.202)
Δln(TFP)			0.021*			0.021
			(0.011)			(0.014)
Δln(Capital/Labor)			0.020			0.037*
			(0.013)			(0.020)
Δln(Labor)			0.007			0.033
			(0.015)			(0.022)
Δln(Wage)			0.004			0.016
			(0.018)			(0.022)
ΔHHI			0.856***			0.432
			(0.239)			(0.306)
Industry Fixed Effect	no	no	yes	no	no	yes
Observations	16,907	16,907	16,907	8,971	8,971	8,971
R-squared	0.0004	0.002	0.017	0.0008	0.004	0.019

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. The dependent variable in specifications (1)-(3) is the (log) price change at the firm-HS6-country level, computed as the log price difference of the same firm-HS6-country triplet from 2001 to 2006. The dependent variable in specifications (4)-(6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term. Herfindahl index (HHI) is computed at the 4-digit CIC industry in China. Industry fixed effect is computed at 2-digit CIC industry level. When we use initial levels of TFP, capital-labor ratio, employment, wage payment, and Herfindahl index to replace the changes in those firm-level and industry-level controls, the similar results obtain: the coefficient of ΔDuty is still significantly negative, and the coefficient for the interaction term is still positive (the coefficients of the interaction terms for the firm-product-country and firm-product regressions are 0.203 and 0.302, respectively).

charged, and this effect is more pronounced for less productive firms.

Besides using the interaction term to distinguish the differential effect of tariff reductions on export prices between less and more productive firms, we test Proposition 3 with dummy variables for the breakout by different productivity levels:

$$\begin{aligned}\Delta\ln(p_{fh(c)}) = {} & \beta_1 \Delta Duty_f \times Low\_TFP_f + \beta_2 \Delta Duty_f \times High\_TFP_f \\ & + \beta_3 \Delta\ln(TFP)_f + \boldsymbol{\beta}_f \Delta\boldsymbol{\chi}_f + \beta_i \Delta HHI_i + \varphi_s + \epsilon_{fh(c)},\end{aligned}$$

where Low_TFP_f and $High\_TFP_f$ are firm-specific dummy variables that are defined by a firm's initial productivity: if its TFP is lower than the median TFP, $Low\_TFP_f = 1$ and $High\_TFP_f = 0$, otherwise $Low\_TFP_f = 0$ and $High\_TFP_f = 1$. The corresponding results at firm-product-country and firm-product levels are reported in columns 1-3 and 4-6 in Table

Table 6: Breakout of the Effect of Tariff Reductions on Export Prices by Different Levels of TFP

	Dependent Variable: $\Delta \ln(price)$					
	$\Delta \ln(p_{fhc})$			$\Delta \ln(p_{fh})$		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty $\times$ Low_TFP	-0.664**	-0.701**	-0.481*	-0.838***	-0.765***	-0.582**
	(0.266)	(0.279)	(0.286)	(0.289)	(0.291)	(0.295)
ΔDuty $\times$ $High\_TFP$	-0.115	0.014	-0.046	-0.329	-0.241	-0.320
	(0.207)	(0.211)	(0.210)	(0.296)	(0.288)	(0.286)
Δln(TFP)			0.030***			0.034**
			(0.011)			(0.014)
Δln(Capital/Labor)			0.022			0.039*
			(0.013)			(0.020)
Δln(Labor)			0.004			0.026
			(0.015)			(0.021)
Δln(Wage)			0.005			0.018
			(0.018)			(0.023)
ΔHHI			0.841***			0.419
			(0.254)			(0.308)
Industry Fixed Effect	no	yes	yes	no	yes	yes
Observations	16907	16907	16907	8971	8971	8971
R-squared	0.001	0.014	0.016	0.001	0.015	0.017

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. The dependent variable in specifications (1)-(3) is the (log) price change at the firm-HS6-country level, computed as the log price difference of the same firm-HS6-country triplet from 2001 to 2006. The dependent variable in specifications (4)-(6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term. Herfindahl index (HHI) is computed at the 4-digit CIC industry in China. Industry fixed effect is computed at 2-digit CIC industry level.

6, respectively, in which columns 1-2 and 4-5 exclude firm-level controls while columns 3 and 6 include those controls. The results clearly show that for low-productivity firms, the effect of tariff reductions on export price increase is more significant and also greater in the magnitude compared to high-productivity firms.[30] Again, similar to the results in Table 5, the coefficient estimates are larger in the more aggregated measures of export prices due to the compositional effect.

According to Proposition 3, the difference between low- and high-productivity firms is more pronounced in industries with large scope for quality differentiation. To address for the predicted slope heterogeneity, we use various approaches to categorize industry's scope for quality differentiation. First, under the reasonable assumption that differentiated goods present greater scope for quality differentiation than do homogeneous goods, we use Rauch's (1999) to create two separate samples. Second, we compute quality variance as quality dispersion across firms within each HS6 product by using the estimated quality (at firm-HS6-

[30] We also conduct regressions using separate samples for more and less productive firms, and obtain results that support Proposition 3 (see Table A.8 in Appendix).

destination level) that is obtained by following Khandelwal, Schott and Wei (2013)'s approach as in Fan, Li and Yeaple (2015) (see more detailed description in the last part of "Robustness II — Alternative Explanations" in Section 5.1.2). Then we use the median of quality variances of all goods to distinguish products with highly-dispersed quality and less-dispersed quality. Lastly, we check our results using the R&D intensity to measure the scope for quality differentiation within an industry (Kugler and Verhoogen, 2012). This measure is based on the argument that firms will only invest in R&D in sectors in which it is possible to affect quality. We use both Chinese and U.S. R&D intensity in this test. Based on Chinese R&D data from the annual surveys of NBSC manufacturing firms, we compute the R&D intensity for each CIC 4-digit industry. We also adopt U.S. R&D intensity based on industry-level information of R&D from U.S. Federal Trade Commission (FTC) Line of Business Survey as in Kugler and Verhoogen (2012).[31]

Table 7: Effect of Tariff Reductions by the Scope for Quality Differentiation

	Quality Differentiation							
	Rauch's (1999)		Quality Dispersion		U.S. R&D intensity		Chinese R&D intensity	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: The scope for quality differentiation is large								
ΔDuty	-2.634***	-3.631***	-2.616***	-4.385***	-2.548***	-3.622***	-2.575**	-4.247***
	(0.810)	(1.145)	(0.924)	(1.419)	(0.937)	(1.328)	(1.117)	(1.307)
ΔDuty × ln(TFP)	0.533***	0.678***	0.568***	0.858***	0.657***	0.872***	0.628**	1.044***
	(0.177)	(0.252)	(0.198)	(0.314)	(0.212)	(0.317)	(0.250)	(0.306)
Observation	15018	7799	8988	4615	9575	5037	7933	4839
R-square	0.017	0.020	0.017	0.028	0.014	0.019	0.022	0.027
Panel B: The scope for quality differentiation is small								
ΔDuty	-0.402	0.562	-2.321**	-2.203**	-2.233**	-2.797**	-2.248**	-2.067*
	(1.170)	(1.138)	(1.015)	(0.948)	(0.951)	(1.128)	(0.885)	(1.086)
ΔDuty × ln(TFP)	0.169	0.024	0.436**	0.403**	0.375*	0.407*	0.396**	0.239
	(0.226)	(0.226)	(0.213)	(0.195)	(0.197)	(0.229)	(0.184)	(0.218)
Observation	1889	1172	7919	4356	7332	3934	7229	3114
R-square	0.058	0.068	0.027	0.022	0.024	0.029	0.022	0.032
Panels A and B:								
Firm-level Controls	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes
Industry Fixed Effect	yes	yes	yes	yes	yes	yes	yes	yes

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses. he specifications (1)-(2) correspond to Rauch's (1999); specifications (3)-(4) correspond to quality dispersion; specifications (5)-(6) correspond to the R&D intensity based on the U.S. data; specifications (7)-(8) correspond to the R&D intensity based on the Chinese data; All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

We report in Table 7, where Panel A reports the results using the subsample where the scope for quality differentiation is large and Panel B report the results using the subsample where the scope for quality differentiation is small. Columns 1-2 refers to differentiated

[31]For the U.S. R&D intensity, we adopt the measure constructed by Kugler and Verhoogen, 2012 and concord to HS6 using the concordance form the UN Comtrade. Using U.S. R&D intensity to examine the role of quality scope on Chinese firms' behavior may be better exempt from the potential issue of the endogeneity of R&D than using Chinese R&D intensity.

goods versus homogeneous goods using Rauch's (1999) classification; columns 3-4 refer to the quality dispersion measure; columns 5-6 are based on R&D intensity computed by the U.S. data; column 7-8 refer to R&D intensity based on the Chinese data. The odd and even columns show results at firm-HS6-country level and firm-HS6 level, respectively.

Table 7 shows that the effect of tariff reductions on price increase is larger in magnitude when the scope for quality differentiation is large. Also, the coefficient on the interaction term that indicates the difference between low- and high-productivity firms is positive and significant in all specifications in Panel A. In contrast, Panel B shows that in the sample where the scope for quality differentiation is small, all coefficients on tariff reduction ($\Delta Duty$) and the interaction term (ΔDuty$\times$log(TFP)) are either insignificant or less significant compared with the ones in Panel A. More importantly, the changes in magnitude and signs of those coefficients in Panel B, compared with Panel A, are consistent with our previous discussion: when scope for quality differentiation becomes smaller, the coefficient on $\Delta Duty$ would increase or even become positive; the coefficient on ΔDuty$\times$ln(TFP) would decrease or even become negative; both coefficients would become less significant.[32] The results in Table 7 confirm the role of quality differentiation as stated in Proposition 3: when the scope for quality differentiation becomes smaller, the effect of tariff reduction on price changes and the differential effect between less and more productive firms would become less pronounced or even become ambiguous. In addition, Panel A reflects the role of compositional effect for industries in which the scope for quality differentiation is high when comparing coefficient estimates in odd columns with those in even columns, but this compositional effect does not occur in industries in which the scope for quality differentiation is small in Panel B.

In the appendix, we show that the results remain unchanged when we experiment with 2-year, 3-year, and 4-year lags (see Table A.9 in Appendix E). In addition, to eliminate the concern of heteroskedasticity, we report the weighted regression results in Table A.10 in Appendix E where Panels A and B present the regression weighted by the number of observations in each 2-digit CIC industry and in each firm, respectively.[33]

5.1.2 Robustness for Main Results

In this subsection, we show the robustness of our results from both statistical and mechanism perspectives. To show the statistical robustness of our results, we conduct four exercises. First, We show our results are robust to various measures of productivity (including physical TFP to remove the concern of revenue-based TFP, other quantity-based measures, labor productivity, and firm size). Second, we confirm the robustness of our results to alternative measures of tariff cuts (including other firm-specific or firm-product-specific measures and the conventional industry-specific tariffs). Third, we use instrumental variable (IV hereafter)

[32]See related discussion after Proposition 3 for theoretical justifications of possible reasons why the coefficient would reverse the sign and the discussion after equation 14 in Section 4.1 for empirical implications).

[33]We also experimented with various weighting schemes (e.g., using export value by each firm as weight), and found no significant difference.

estimation to address the potential issue of the endogeneity of tariff reductions and obtain similar results. In addition, we show that our results are not biased toward big firms using the whole customs data without matching the data to the manufacturing firm survey.

From the mechanism perspective, we show that our results are not sensitive to other explanations of the results based on three exercises. First, we conduct a placebo test that is intended to verify the model mechanism through imported intermediate inputs. Second, we present various sensitivity tests to eliminate the concern that our results might be spuriously picking up the effect through other mechanisms (such as reduced policy uncertainty and currency appreciation) rather than the import tariff reduction effect through imported intermediate inputs. Lastly, we report results that directly test the quality upgrading mechanism through estimated quality.

A. Robustness I — Statistical

Table 8: Quantity-Based Productivity Measures

	Dependent Variable: $\Delta \ln(price)$					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Firm-level Physical TFP						
ΔDuty	-0.959**	-0.923*	-1.071**	-0.983*	2.032	0.050
	(0.436)	(0.511)	(0.443)	(0.519)	(1.514)	(2.640)
ΔDuty $\times$ ln(TFP)	0.693*	0.441	1.206**	1.017*	0.009	0.223
	(0.384)	(0.337)	(0.541)	(0.530)	(0.396)	(0.438)
Observation	4007	2326	3559	2105	448	221
R-square	0.031	0.025	0.036	0.029	0.141	0.185
Panel B: Firm-product productivity proxy based on HS6						
ΔDuty	-1.110**	-1.625**	-1.411**	-1.994**	0.934	1.455
	(0.540)	(0.700)	(0.597)	(0.775)	(0.864)	(1.190)
ΔDuty $\times$ ln(TFP)	0.091**	0.127**	0.116**	0.148**	-0.041	-0.058
	(0.045)	(0.056)	(0.053)	(0.065)	(0.057)	(0.079)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.066	0.064	0.068	0.071	0.089	0.079
Panels A and B:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Industry fixed effect Control	yes	yes	yes	yes	yes	yes

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level. When we use firm-product productivity proxy based on HS4 product, the similar results as in Panel B obtain.

(A.1) Alternative measures of productivity and firm size.— As our focus is the effect of initial productivity on firms' response to tariff reductions, it is important to show that our

results are robust to different approaches of estimating firm productivity. Table 8 reports robustness checks using quantity-based productivity measures. Panel A presents results based on physical TFP (see Section 4.3 for the discussion on the measurement issues and estimation approach). The first two columns correspond to the whole sample, columns 3-4 use the subsample of differentiated goods, columns 5-6 refer to homogeneous goods, where the odd and even columns use firm-HS6-country and firm-HS6 level price change as dependent variable, respectively.[34] For all goods and differentiated goods, all coefficients on tariff changes are significantly negative and the ones on the interaction term are positive. The effect of tariff reductions for differentiated goods are always larger than the effect for all goods across all specifications, while for homogeneous goods the effect is insignificant. This pattern is consistent with the prediction of Proposition 3 that the effect of tariff reduction on price changes and the differential effect between less and more productive firms would become less pronounced when the scope for quality differentiation becomes smaller.

Other quantity measures reported in Table 8 use firm-product level export quantity as a rough proxy for firm-product level productivity (see Panel B when using firm-HS6 product definition). All previous main results are robust when using export quantity as proxy for firm-product productivity: low-productivity firms are more affected by tariff reductions and increase their export prices more, especially in the sample of differentiated goods where the scope for quality differentiation is large.

In addition, we use other variables, such as valued added per worker, total sales and total employment payment to replace firm productivity.[35] Table A.1 in the appendix shows that the main results hold when using other variables as proxy for productivity: all coefficients on tariff changes are significantly negative and the ones on the interaction term of tariff change and initial productivity are positive for all goods and for differentiated goods. The effect of tariff reductions for differentiated goods are always greater than the effect for all goods across all specifications, while for homogeneous goods the effect is insignificant.

(A.2) Alternative measures of tariff cuts.— So far our discussion is based on the main measure of firm-specific tariff reductions that has the advantage of being theoretically justified and consistent with the intensive margin effect across firms. In Section 4.2 we also discussed various approaches to measure the impact of tariff cuts at different aggregation levels and their features. We now show the robustness of our results with those alternative tariff reduction measures, including other firm-specific or firm-product specific tariff cuts and industry-specific tariff reductions.

In Table 9, columns 1-2 refer to the first alternative measure of tariff cuts using fixed set of imported inputs, columns 3-4 adopt tariffs only of intermediate goods, and columns 5-6

[34]Here, the magnitude of the coefficient estimates is not always larger at more aggregated level, perhaps due to the sample size change that we only keep single-product firms.

[35]Here, we use the total employment payment instead of the total employment number, because firm with different productivity pay different wages due to different levels of labor's effort based on our model. To drop outliers, we also delete the firms with the total employment payment below 1 percentile, around forty thousand dollars.

Table 9: Robustness: Alternative Measures of Firm-Specific Tariff Cuts

	Alternative Tariff Reduction Measures					
	Measure 1		Measure 2		Measure 3	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Whole Sample						
ΔDuty	-1.895***	-2.049**	-2.298***	-2.698***	-2.615***	-2.649**
	(0.601)	(0.957)	(0.724)	(1.004)	(0.790)	(1.190)
ΔDuty $\times$ ln(TFP)	0.421***	0.459**	0.472***	0.526**	0.603***	0.605**
	(0.128)	(0.213)	(0.154)	(0.215)	(0.175)	(0.249)
Observation	21922	11750	15229	8121	9626	4704
R-square	0.013	0.015	0.018	0.019	0.021	0.025
Panel B: Differentiated Goods						
ΔDuty	-2.064***	-2.184**	-2.539***	-3.183***	-2.708***	-2.944**
	(0.672)	(1.046)	(0.844)	(1.219)	(0.899)	(1.397)
ΔDuty $\times$ ln(TFP)	0.475***	0.525**	0.514***	0.606**	0.616***	0.679**
	(0.144)	(0.236)	(0.184)	(0.271)	(0.203)	(0.300)
Observation	19630	10290	13426	7025	8682	4154
R-square	0.012	0.015	0.019	0.020	0.023	0.027
Panel C: Homogeneous Goods						
ΔDuty	-0.416	-0.343	0.228	1.891	-0.016	-1.553
	(1.006)	(1.518)	(1.365)	(1.601)	(2.175)	(1.953)
ΔDuty $\times$ ln(TFP)	0.024	-0.040	0.074	-0.186	0.075	0.239
	(0.196)	(0.321)	(0.247)	(0.281)	(0.417)	(0.391)
Observation	2292	1460	1803	1096	944	550
R-square	0.047	0.060	0.055	0.068	0.059	0.085
Panels A, B and C:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Industry fixed effect	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Measure 1 (see specifications 1 and 2) refers to the tariff reduction measure by fixing the total number of imported varieties during the whole sample period; measure 2 (see specifications 3 and 4) is the weighted firm-specific import tariff reductions of only intermediate goods; measure 3 (see specifications 5 and 6) refers to Manova and Zhang (2012*b*)'s method of computing the input within the same product category. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

use Manova and Zhang (2012*b*)'s method of computing the input within the same product category. Panel A reports the results in the whole sample, Panel B presents the results using the differentiated goods sample, and Panel C reports the results with the homogeneous goods sample. The firm-HS6-country level results are presented in columns 1, 3, and 5, while the firm-HS6 product level results are presented in columns 2, 4, and 6.

Note that the sample size differs for different measures of tariff cuts: moving from the main measure or measure 1 to measure 2 (based on the set of imported intermediates to those clearly classified) and measure 3 (based on the inputs only within the same product category) reduces the sample size, but does not alter the estimated relationships. Table 9 shows that for all goods and differentiated goods, the effect of tariff reduction on export price and the difference between low- and high-productivity firms are all significant and consistent with our model predictions. The results of differentiated goods are always stronger than the ones for all goods across all specifications, while the effect of interest is not significant for homogeneous goods. This again corroborates Proposition 3.

Table 10: Robustness: Results of Industry Input and Output Tariffs

	Dependent Variable					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Level regression (Dependent variable = ln(price))						
Duty^{input}	-1.502*	-1.855	-1.782**	-2.346**	0.105	0.852
	(0.881)	(1.183)	(0.792)	(0.925)	(0.899)	(0.893)
$\text{Duty}^{input} \times \ln(\text{TFP})$	0.207*	0.259*	0.241**	0.333**	0.085	-0.041
	(0.106)	(0.135)	(0.117)	(0.137)	(0.146)	(0.178)
Duty^{output}	0.288	0.240	0.392*	0.366	-0.448	-0.529
	(0.213)	(0.261)	(0.208)	(0.257)	(0.475)	(0.533)
Year fixed effect	yes	yes	yes	yes	yes	yes
Firm-HS6-country fixed effect	yes	no	yes	no	yes	no
Firm-HS6 fixed effect	no	yes	no	yes	no	yes
Observation	1302884	471128	1144122	407363	158762	63765
R-square	0.980	0.968	0.980	0.968	0.975	0.959
Panel B: Difference estimation (Dependent variable = Δln(price))						
$\Delta\text{Duty}^{input}$	-3.002***	-3.698***	-3.325***	-4.153***	-2.121	-1.144
	(0.967)	(1.421)	(0.997)	(1.449)	(1.559)	(2.068)
$\Delta\text{Duty}^{input} \times \ln(\text{TFP})$	0.373**	0.569*	0.423**	0.733**	0.409	-0.281
	(0.176)	(0.295)	(0.198)	(0.337)	(0.280)	(0.365)
$\Delta\text{Duty}^{output}$	0.843***	0.863*	0.888***	0.741	0.399	1.490
	(0.294)	(0.481)	(0.303)	(0.508)	(0.730)	(1.012)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.005	0.005	0.005	0.006	0.006	0.008
Panels A and B:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the 4-digit CIC industry level in parentheses. Dependent variable in Panel A is (log) price level; dependent variable in Panel B is the (log) price change. In columns 1, 3, and 5, we use firm-HS6-country price level or price change; in columns 2, 4, and 6, we use firm-HS price level or price change. All regressions include a constant term, firm-level controls, and industry-level competition control. Firm-level controls refer to the levels (in Panel A) or the changes between 2001 and 2006 (in Panel B) of the following variables: TFP, capital intensity, average wage, and total employment. Industry-level competition control refers to Herfindahl index (in Panel A) and the change of Herfindahl index (in Panel B).

One might worry that the correlation between the reduction in import tariffs on intermediate inputs and tariff cuts on firms' outputs might cause the coefficient estimates to be polluted by competition effects (Amiti and Khandelwal, 2013). Moreover, as discussed in Section 4.2, while the firm-specific measures of tariff cuts have advantages, they may miss the broader effect of tariff cuts on intermediate inputs when firms use domestically purchased intermediate inputs that are imported by other firms. We address these concerns by including output tariffs and input tariffs constructed using input-output tables.[36]

Table 10 reports results of both level regressions (see Panel A) and difference estimations (see Panel B). In Panel A, the dependent variable is (log) price at firm-HS6-destination level in odd columns and (log) price at firm-HS6 level in even columns. To better capture the variation of export prices over time, we control for year fixed effects and firm-HS6(-country) fixed effect in level regressions. The coefficients on input tariff are mostly significant and negative, and the coefficients on the interaction term are always significantly positive, for the samples of all goods and differentiated goods, even after precisely controlling for firm-HS6(-destination) fixed effects. This pattern is more profound when using difference estimations in Panel B. To sum up, using industry-level input tariff does not alter our main results even after taking into account the effect of output tariff and firm-product(-country) fixed effect.

(A.3) Endogeneity.— Now, we address the issue of the potential endogeneity of tariff changes, though we believe that tariff changes are arguably exogenous from the individual firm's perspective. Using industry-specific input tariffs alleviates the concern of the endogeneity of tariff cuts to some extent, but cannot fully eliminate the concern. To throughly address the endogeneity issue, we also report IV estimation results with the past levels of tariffs as instruments for changes in tariffs that is commonly used in the literature (e.g., Goldberg and Pavcnik, 2005; Amiti and Konings, 2007). The idea is that the past tariffs are usually strongly correlated with the current changes in tariffs, but the past tariffs are uncorrelated with the error term or any other determinants of the dependent variable in the baseline regressions (i.e., the exclusion restriction). Therefore, we can employ past levels of tariffs as instruments. Because the results of instrument are not qualitatively different, they are reported in Table A.2 in Appendix D in order to conserve space.

(A.4) Large sample test using whole customs data.— So far our results are based on a merged sample based on the NBSC firm production data and the customs data. One may concern about the sample selection issue as the NBSC data only record above-scale non-SOE and all SOE manufacturing firms that are usually large firms. To alleviate this concern, we present results using the whole customs data where total export value is used as proxy for firm productivity and HS2 product fixed effects are included as industry fixed effects. As the results are strongly consistent our benchmark results, we present them in Table A.3 in Appendix D to conserve space.

B. Robustness II — Alternative Explanations

[36]We map the harmonized system (HS) 8-digit tariffs into the 5-digit Chinese Input-Output industry code. Our 5-digit output tariff, then, is the simple average of the tariffs in the HS 8-digit codes within each 5-digit IO industry code. To compute the input tariff, following Amiti and Konings (2007) we use an input cost weighted average of output tariffs where:$\tau_{it}^{input} = \sum_k a_{ki}\tau_{kt}^{output}$ where τ_{kt}^{output} is the tariff on industry k at time t, and a_{ki} is the weight of industry k in the input cost of industry i. Then we convert the input tariffs to CIC 4-digit industry level.

(B.1) Placebo test using processing trade.— Note that our previous results are all based on ordinary trade firms that pay import tariffs to import intermediate inputs. Now we replicate our baseline regressions using processing trade firms as a comparison group and confirm the mechanism of our model through the placebo test because processing firms are not subject to import tariffs. Since our model highlights the channel through the improved access to imported intermediate inputs, we expect that processing trade firms do not respond significantly to tariff reductions and certainly there is no difference of the response between low- and high-productivity processing firms. Table A.5 in Appendix D reports the results using processing trade sample and confirms our expectation. All coefficients on tariff reductions and interaction terms are statistically insignificant for whole sample and for the differentiated goods sample.

(B.2) Sensitivity to other mechanisms.— One may concern that there are other mechanisms through which trade liberalization affects low- and high-productivity firms differently regarding their export price changes. Those potential mechanisms include reduced uncertainty that restraints Chinese firms' ability to export to certain markets, especially those high-income countries where demand for high quality goods is strong, and appreciation of Chinese currency.

Policy uncertainty.— Prior to its accession to the WTO, China was vulnerable to the sudden loss of MFN status in its trade relations with the United States, where such status required annual congressional action to maintain. Pierce and Schott (2013) have shown that this vulnerability depressed Chinese exports to the U.S., particularly in industries where non-MFN tariffs were very high. To role out the potential for this mechanism to drive our results, we remove the U.S. from our sample and reestimated our main equations. The resulting estimates for all goods, differentiated goods, and homogeneous goods are shown in columns 1, 4, and 7 in Table A.6 in Appendix D, respectively.

Currency appreciation.— As China's currency, *Reminbi* (RMB), has appreciated since July 2005, one may be also concerned that the price increase is partially due to the appreciation of RMB. It is possible that a stronger RMB reduces firms' costs to purchase imported inputs with local currency, and thus provides firms more incentive to switch to better inputs. To test the sensitivity of our results to RMB appreciation, we use the data during the period before the appreciation to test whether export prices indeed increase without currency appreciation. As the RMB appreciated in late 2005, we dropped data of 2005 and 2006, and conduct the long-difference estimation for the period between 2001 and 2004 in columns 2, 5 and 8 for firm-HS6-country level price change ($\Delta \ln p_{fhc}$) and columns 3, 6, and 9 for firm-HS6 level price change ($\Delta \ln p_{fh}$) in Table A.6, respectively.

(B.3) The test using estimated quality.— It is not easy to directly measure quality, but we can infer "effective quality" (quality as it enters consumer's utility) from observed prices and market shares. We estimate "quality" of exported product h shipped to destination country c by firm f in year t, q_{fhct}, according to demand equation (1) in the model, using an OLS

regression as in Khandelwal, Schott and Wei (2013) and Fan, Li and Yeaple (2015), via the following empirical demand equation in our model:

$$\ln(x_{fhct}) + \sigma \ln(p_{fhct}) = \varphi_h + \varphi_{ct} + \epsilon_{fhct} \tag{15}$$

where x_{fhct} denotes the demand for a particular firm's export of product h in destination country c in year t, p_{fhct} is the price the firm charges that equals the price that consumers face, σ is the elasticity of substitution across products, the country-year fixed effect φ_{ct} collects the destination-year specific information including price index and expenditure at destination markets, and the product fixed effect φ_h captures the information on prices and demand across product categories due to the inherent characteristics of products. Then estimated quality is $\ln(\hat{q}_{fhct}) = \hat{\epsilon}_{fhct}$, i.e., the residual from equation (15).[37] We then allow the elasticity of substitution to vary across industries (σ_i) using the estimates of Broda and Weinstein (2006) to estimate quality.[38]

The results using estimated quality as dependent variable are reported in Table A.7 in Appendix D. The results present a similar pattern as in our main results in which price changes are dependent variable. In the whole sample of all goods and the sample of differentiated goods, tariff reductions significantly induce firms to upgrade quality of their products, and this quality upgrading pattern is more profound for low-productivity firms as shown by the significantly positive coefficients on the interaction term. This pattern does not appear in the homogeneous goods sample.

(B.4) Controlling for Mark-Up Changes.—To further verify quality upgrading by firm's access to higher quality inputs, we check whether the effect of tariff reduction on price increase along the intensive margin still exists after controlling markup variation. To this end, we include change in market share in our estimation to control change in markup because firm's market share is an indicator of its markups (see Amiti, Itskhoki and Konings (forthcoming) and Fan, Li and Yeaple (2015)). In specifications (1), (3) and (5) of Table A.11 in the Appendix, we add change in firm's market share as control variable to test impact of tariff reduction on $\Delta \ln p_{fhc}$, for all goods, differentiated goods and homogeneous goods, respectively. In accordance, coefficients on tariff reductions are significantly negative, while coefficients on interaction terms (ΔDuty $\times$ log(TFP)) are significantly positive for all goods and differentiated goods. As for homogeneous goods, all effects are, however, insignificant. This alleviates the concern that our results reflect markup variation rather than quality adjustments along the intensive margin. To address the potential endogeneity of market share

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

[38] Using the existing values of estimated σ from the literature is a common approach used in the prior studies (e.g., Khandelwal, Schott and Wei, 2013). Broda and Weinstein (2006) estimate the elasticity of substitution for disaggregated categories and report that the average and median elasticity is 7.5 and 2.8, respectively. We use their estimates aggregated to HS 2-digit level and merge with our sample. In addition, to avoid parameterizing σ_i based on the existing values given in the literature, we also estimate quality using IV estimation and our results remain robust. To save space, the results based on estimated quality using IV estimation are not reported here, but available upon request.

change, we employ initial tariff levels in 2001 (see columns 2, 4 and 6) facing all other firms in the same 4-digit CIC industry to instrument market share change for each individual firm. Again, the effect of tariff reductions on price increase across firm would not be affected by instrumenting for market share changes.

5.2 Tariff Reduction and Input Quality Upgrading

In this section, we explore the input price implications of our model. According to Proposition 4, a reduction in import tariff would induce an incumbent exporter/importer to pay higher prices for both its primary and intermediate inputs. That is to say, the increase in export prices would go through two channels of input quality upgrading: an increase in the primary input quality involving better workers that require higher wage payment and the upgrade in the quality of imported intermediate inputs. Moreover, this effect is smaller in absolute magnitude for more productive firms, and the differential effect between low- vs. high-productivity firms is most pronounced in industries in which the scope for quality differentiation is high (low η).

Table 11: Input Quality Upgrading (I): Wage Upgrading, Tariff Cuts, and Productivity

	Dependent Variable: Change in Wage Payment at Firm Level								
	Whole Sample			large scope of quality differentiation			small scope of quality differentiation		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	-0.509*	0.142	-1.377*	-1.013**	-0.003	-2.816**	-0.491	0.170	-0.623
	(0.261)	(0.189)	(0.718)	(0.473)	(0.380)	(1.285)	(0.318)	(0.220)	(0.776)
ΔDuty$\times$ln(TFP)			0.288*			0.563**			0.155
			(0.150)			(0.257)			(0.164)
Observation	2129	2128	4257	1125	1008	2133	1004	1120	2124
R-square	0.0018	0.0003	0.092	0.0041	0.00001	0.056	0.0024	0.0005	0.142
Firm-level Controls	no	no	yes	no	no	yes	no	no	yes
Industry-level Competition Control	no	no	yes	no	no	yes	no	no	yes
Industry Fixed Effect	no	no	yes	no	no	yes	no	no	yes
Cluster at Firm Level	no	no	yes	no	no	yes	no	no	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses in specifications 3, 6, and 9. We use Chinese data on R&D intensity to differentiate the sector where the scope for quality differentiation is large (in columns 4-6) or small (in columns 7-9). All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: capital intensity, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

Table 11 report the results of regressing firm-level wage payment changes on tariff reduction and its interaction with initial productivity. Columns 1-3 show results for whole sample; columns 4-6 and 7-9 report results for firms in industries where the scope for quality differentiation is large and small based on the median of R&D intensity, respectively.[39] In each of the three columns, the first column uses the subsample of low-productivity firms, the second

[39] Here we adopt R&D intensity based on Chinese data to categorize industry's scope for quality differentiation, because the firm-level wage data cannot be categorized by the Rauch's classification.

Table 12: Input Quality Upgrading (II): Import Price Upgrading, Tariff Cuts, and Productivity

	Dependent Variable: Import Price					
	Firm-product-country level			Firm-product level		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Whole Sample						
ΔDuty	-0.740*	0.275	-1.325	-0.778*	0.038	-1.587
	(0.419)	(0.262)	(1.133)	(0.423)	(0.297)	(1.015)
ΔDuty×ln(TFP)			0.314			0.352*
			(0.207)			(0.195)
Observation	10711	10668	21379	10598	10429	21027
R-square	0.0003	0.0001	0.007	0.0003	0.00001	0.008
Panel B: Differentiated Goods						
ΔDuty	-1.203**	0.862**	-1.800	-1.322**	0.253	-1.927
	(0.538)	(0.432)	(1.453)	(0.553)	(0.430)	(1.340)
ΔDuty×ln(TFP)			0.510*			0.449*
			(0.284)			(0.267)
Observation	8879	8580	17459	8780	8346	17126
R-square	0.0006	0.0005	0.008	0.0007	0.00004	0.008
Panel C: Homogeneous Goods						
ΔDuty	0.280	-0.159	-0.325	0.226	-0.192	-0.790
	(0.447)	(0.202)	(0.710)	(0.453)	(0.278)	(0.761)
ΔDuty×ln(TFP)			0.0720			0.171
			(0.119)			(0.139)
Observation	1832	2088	3920	1818	2083	3901
R-square	0.0002	0.0002	0.021	0.0001	0.0002	0.017
Panels A, B and C:						
Firm-level Controls	no	no	yes	no	no	yes
Industry-level Competition Control	no	no	yes	no	no	yes
Industry Fixed Effect	no	no	yes	no	no	yes
Cluster at Firm Level	no	no	yes	no	no	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses in specifications 3 and 6. Specifications (1) and (4) use subsample of firms with initial productivity below median; specifications (2) and (5) use subsample of firms with initial productivity above median. Specifications (3) and (6) use whole sample. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is at 2-digit CIC industry level.

is for high-productivity firms, and the last is for all firms. The results show that the tariff reduction increased wages for low-productivity firms in the whole sample and in the industries with large scope for quality differentiation (see columns 1 and 4), and the coefficients on the interaction terms are also consistent with model predictions (see columns 3 and 6). Furthermore, the effect is more pronounced in industries where the scope for quality differentiation is large when we compare the magnitude of coefficients in columns 4 and 6 versus those in columns 1 and 3. Meanwhile, the effect of trade liberalization on wages are not significant in industries where the scope for quality differentiation is small (see columns 7-9).

Table 12 report the regression results with import prices (at either firm-product-country level in columns 1-3 or firm-product level in columns 4-6) as dependent variable and show

how the changes in import prices depend on tariff reductions and initial productivity. We first regress based on subsamples of low productivity firms (see columns 1 and 4) and high productivity firms (see columns 2 and 5) separately, and then use interaction term with initial productivity for all firms (see columns 3 and 6). The regressions are conducted for all goods (in Panel A), differentiated goods (in Panel B), and homogeneous goods (in Panel C). In columns 1 and 4 when we regress import price changes on tariff reduction using low productivity firms, all coefficients on tariff changes are significantly negative for all goods (in Panel A) and differentiated goods (in Panel B), but insignificant for homogeneous goods (in Panel C). In columns 2 and 5, the coefficients show that the responses from more productive firms are weaker.[40] In columns 3 and 6, the coefficients on the interaction term of tariff changes and initial productivity are significantly positive, especially for differentiated goods, while the coefficients in homogeneous goods sample are insignificant. These results are again consistent with Proposition 4 that in the industries where the scope for quality differentiation is large, trade liberalization has greater effect on import price increase, especially for less productive firms.

5.3 Evidence at Extensive Margin

As discussed in the theory section, an immediate extension of our model with market penetration costs that are increasing in market demand can generate an extensive margin of market entry that is a function of input costs. Such an extension suggests that a tariff reduction on imported intermediates ought to affect the composition of destination markets of less productive firms by more than it affects the composition of destination markets of more productive firms.

To examine the pattern along the extensive margin, within the same firm-HS6 product (hereafter fh, for short), we distinguish three types of markets, namely, "continuing", "entry", and "exit" according to their status in the pre-liberalization period (2001) and post-liberalization period (2006). If a destination market for a fh combination exists in both 2001 and 2006, it is defined as "continuing" type; if it appears in 2006 but not in 2001, it is characterized as "entry" type; if it appears in 2001 but not in 2006, it is characterized as "exit" type. Then we compare the changes in (log) export prices and in (log) incomes (GDP per capita) of destination markets for different types of markets using a mean or median fh combination (see Table 13).

In Table 13, we compute the following measures of changes in export prices (see Panel A) and changes in incomes of countries across destination markets (see Panel B) within the same firm-product: (1) the price/income change for all markets and continuing markets, and

[40] In industries where the scope for quality differentiation is large (in Panel B), the sign of coefficient on tariff change becomes significantly positive because the import price of intermediate inputs is cif price that includes tariff in Chinese customs data.

Table 13: Changes at the Extensive Margin: Destination Market Types and Initial Productivity

	All Markets		Continuing Markets		Entry vs. Exit	
	(1)	(2)	(3)	(4)	(5)	(6)
	≤50th	>50th	≤50th	>50th	≤50th	>50th
Panel A: changes in export prices at firm-product level						
Per Firm-product, median	15.24%	8.21%	13.73%	7.71%	18.09%	9.31%
Per Firm-product, mean	20.57%	11.99%	19.53%	10.56%	22.16%	14.25%
Panel B: changes in incomes of destination markets						
Changes in Mean Incomes of Destination Markets:						
Per Firm-product, median	24.79%	22.34%	22.34%	22.34%	35.98%	31.73%
Per Firm-product, mean	31.12%	27.53%	27.13%	26.14%	37.32%	29.73%
Changes in Median Incomes of Destination Markets:						
Per Firm-product, median	24.80%	22.34%	22.34%	22.34%	40.28%	34.42%
Per Firm-product, mean	31.56%	28.28%	26.88%	26.05%	38.82%	31.82%

Notes: ≤50th indicates the firms associated with lower initial productivity (i.e., the bottom 50th percentile); >50th indicates the firms associated with higher initial productivity (i.e., the top 50th percentile). Prices and incomes are in logarithm. Productivity in this table refers to labor productivity computed as value added per worker. When using other measures of TFP, the similar pattern also holds.

(2) the price/income change for markets of "entry" versus markets of "exit".[41] Within each firm-product, the price change for "entry-exit" is computed by the average price of each firm-product across all its newly added markets (markets of entry) in 2006 minus the average price across all its dropped markets (markets of exit) in 2001. As for changes in incomes of destination markets, we take either mean or median incomes across destinations within each firm-product in 2001 and 2006, and then compute the change over time for each type of market within the same firm-product. We present the mean and median price and income change for all markets, continuing markets, and switching markets (entry vs. exit) in columns 1-2, 3-4, and 5-6, respectively.

The first important message conveyed by Table 13 is that the quality upgrading pattern along extensive margin relates to firm productivity. To show this, we divide sample into low-productivity and high-productivity firms by median in each type of markets. For all three types of markets, the price increase for low-productivity firms is greater than that for high-productivity firms (see the odd columns vs. even columns). The average incomes of destination markets also present the pattern that less productive firms have greater increase than more productive firms with the only exception at continuing markets.

We then compare different types of markets in Table 13. We start with continuing markets (see columns 3 and 4) that reflect the intensive margin effect. The export price increases is greater for less productive firms than for more productive firms at continuing markets, which is fully consistent with the model prediction due to quality upgrading at the intensive margin; while the difference between the average income of destinations for low- versus high-

[41] According to the literature (e.g., Manova and Zhang (2012*a*)), there is a positive correlation between product quality and income of destination markets, i.e., firms charge higher export prices in richer markets because they sell higher quality goods there. Hence, we study changes in incomes of destination markets as evidence at extensive margin.

productivity firms is not obvious because the effect occurs at the same markets. When we move to all markets in columns 1-2, due to compositional shift at the extensive margin, i.e., firms are able to enter more high-income markets where the demand for high quality goods is strong so they charge higher export prices, we observe greater increase in prices and average income, especially for low-productivity firms (see column 1 vs. column 3). This again is fully consistent with our model prediction that under trade liberalization, firms start exporting to markets with strong demand for high quality goods along extensive margin, especially for those less productive firms. In addition, we provide more indirect evidence at the extensive margin through switching markets in the last two columns in Table 13: the price and income increase for low-productivity firms in switching markets (entry vs. exit) is in the greatest magnitude (see column 5 vs. other columns).

Table 14: Heterogeneity in the Effect of Tariff Reductions across Different Types of Markets

	All Markets			Continuing Markets			Markets of Entry vs. Exit		
	Dependent Variable								
	$\Delta \ln(p_{fh})$	$\Delta \ln(Income_{fh})$		$\Delta \ln(p_{fh})$	$\Delta \ln(Income_{fh})$		$\Delta \ln(p_{fh})$	$\Delta \ln(Income_{fh})$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	-3.084***	-1.379*	-1.298*	-2.332***	0.292	0.284	-3.970**	-3.671**	-4.102**
	(0.930)	(0.707)	(0.710)	(0.870)	(0.282)	(0.289)	(1.568)	(1.652)	(1.672)
ΔDuty$\times$ln(TFP)	0.592***	0.271*	0.257*	0.446**	-0.035	-0.031	0.855**	0.841**	0.910**
	(0.202)	(0.150)	(0.150)	(0.187)	(0.057)	(0.058)	(0.351)	(0.365)	(0.379)
Firm-level Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes	yes	yes	yes
Industry Fixed Effect	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	8971	8741	8741	6994	6731	6731	4571	4387	4387
R-squared	0.019	0.009	0.008	0.017	0.095	0.078	0.022	0.018	0.017

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. The dependent variable in specifications (1), (4), and (7) is the (log) price change at the firm-HS6 level. The dependent variable in specifications (2)-(3), (5)-(6), and (8)-(9) is the (log) income change at the firm-HS6 product level, where columns 2, 5, and 8 use mean income and columns 3, 6, and 9 use median income. Columns 1-3, 4-6, and 7-9 correspond to all markets, continuing markets, and markets of entry versus exit, respectively. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

Finally, we replicate baseline regressions using the price or income change for different types of markets as dependent variable and report results in Table 14. Columns 1-3, 4-6, and 7-9 correspond to all markets, continuing markets, and markets of entry vs. exit, respectively. Again, we start with continuing markets (intensive margin effect, see columns 4-6) that is the focus of our paper. At continuing markets, the price increase significantly depends on initial productivity and the coefficients on the interaction term are significant and consistent with the predicted sign (see column 4); while the income increase and its relation to productivity is not significant at continuing markets which is not surprising (see columns 5-6). When we move to all markets in columns 1-3, both price increase and income increase become significantly depending on tariff reduction and initial productivity, due to the compositional effect. Lastly, the switching markets present the strongest pattern regarding the magnitude of coefficients (see columns 7-9 vs. columns 1-3 and 4-6). This indicates that incumbent firm-product pairs indeed switch from the lower income markets where demand for high quality goods is weak and products are sold at lower prices to higher income markets where demand for high quality goods is strong and products are sold at higher prices, and this pattern is more pronounced for low-productivity firms. All together, the evidence at the extensive margin corroborates our quality upgrading mechanism at the intensive margin.

6 Conclusion

This paper studies the relationship between quality and productivity under trade liberalization and highlights the heterogeneous response across firms to import tariff reductions. We use highly disaggregated firm-product-level data and the shock of China's entry into the WTO to trace through the manner in which trade liberalization on intermediate inputs induced Chinese firms to upgrade their input and output quality. We find that quality upgrading is primarily achieved by the initially less successful Chinese firms. In other words, the chief beneficiaries of liberalized intermediate input tariffs are not the initially most productive firms but are instead the less productive firms that are operating in industries in which the scope for quality variation is the most pronounced. When initially more capable firms run into diminishing returns to quality upgrading, it is precisely those lower productivity firms that are most likely to upgrade the quality of their exports, increase the quality of their imported intermediates, and upgrade their workforces. They are also more aggressive in entering new, high income markets where demand for high quality goods is strong along the extensive margin. As a result, the gap between low and high productivity firms regarding their quality performance would be reduced under an import tariff reduction. In this sense, trade liberalization appears to have evened the playing field with respect to firm performance.

To explain these facts, we developed a simple heterogeneous-firm trade model that relates a firm's input and output quality choice to its imported intermediates and productivity. The model predicts that low productivity firms are induced to raise their output prices and quality more than high productivity firms do under a reduction in import tariffs. Meanwhile, they increase input prices more for both primary inputs and intermediate inputs than high productivity firms. In addition, at the extensive margin, low productivity firms expand destination markets by entering those with relatively strong demand for high-quality goods. Those tariff reduction effects are more pronounced in industries where the scope for quality differentiation is large.

Our finding has important policy implications that low productivity incumbent firms are potential winners from trade liberalization and this alleviates the concern that trade liberalization hurts small and less productive firms. There exists intriguing possibility that a high level of protection may favor firms that are particularly well suited for this environment.

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Appendix

A Supplementary Figure

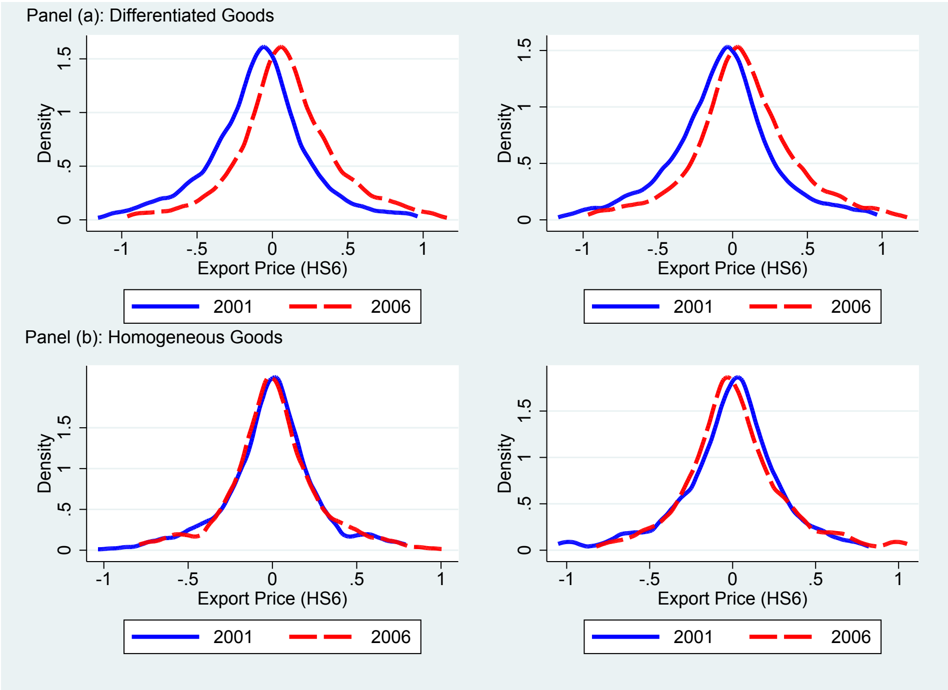

Figure A.1: Distributions of Export Prices by Initial Productivity and Product Heterogeneity (HS6 products)

Notes: Prices for continuing firm-HS6 pairs are in logarithm. Graphs in the top panel refer to firms with lower initial productivity (i.e., productivity lower than the median) and graphs in the bottom panel refer to firms with higher initial productivity (i.e., productivity above the median). Price distributions are drawn by regressing export prices on firm-HS6 fixed effects and then plotting the residuals, as in De Loecker et al. (forthcoming). The two graphs in the right panel refer to whole sample, the two graphs in the middle panel refer to differentiated goods, and the two graphs in the bottom panel refer to homogeneous goods.

B A Simple Microfoundation for Price Setting

Consider an industry i. In this industry, a firm with productivity φ produces output with quality q according to the following production function for quality:

$$q(\varphi) = g^{-1}\left[\varphi\left(\frac{e_v}{1-\mu_i}\right)^{1-\mu_i}\left(\frac{q_{iM}}{\mu_i}\right)^{\mu_i}\right] \tag{16}$$

where e_v is the final-good worker's effort (or the quality of labor inputs in producing final good), q_{iM} is the quality of the composite intermediate inputs, $\mu_i \in (0,1)$.

The quality of composite intermediate input, q_{iM}, is costlessly assembled from a continuum of intermediates that are indexed by $m \in [0,1]$ according to the following function:

$$q_{iM} = \min \{q_i(m) | \forall m\} \tag{17}$$

where $q_i(m) \equiv q_{im}$ is the quality of intermediate input m. The intermediate input market is perfect competition. Producing one unit of an intermediate input of quality $q_{im} = a(m) e_{im}$ depends on the intermediate-good worker's effort e_{im} and intermediate-good producer's productivity $a(m)$. Plants face worker quality-wage schedules that are assumed to be upward-sloping and, in the interest of simplicity, linear:

$$e_v = \kappa_v w_v \tag{18}$$

$$e_{im} = \kappa_{im} w_{im} \tag{19}$$

where w_v and w_{im} are the wages of final-good and intermediate-good worker on a particular production line and κ_v and κ_{im} are positive constants.

For a cost minimizing firm, $q_{im} = q_{iM}$ for all m. If the firm purchases intermediate m with quality q_{im} locally, it pays the domestic unit price $c_d(m)q_{iM} = \frac{1}{\kappa_{im}a(m)}q_{iM}$, where $c_d(m) = \frac{1}{\kappa_{im}a(m)}$ denotes the cost to produce unit quality by domestic intermediate-good producer. If the firm imports the intermediate m with quality q_{im}, then it must first pay the unit price of $\tau c_f(m)q_{iM}$, where $\tau c_f(m)$ denotes the cost to produce unit quality by foreign intermediate-good producer and $\tau > 1$ is one plus the tariff rate, with the foreign country denoted by an asterisk.

To be simplified, we assume that $c_d(m) \equiv c_d$ is a constant and $c_f(m)$ is strictly decreasing and continuous in m. Hence, foreign producers have a comparative advantage in high m goods and domestic producers have a comparative advantage in low m goods. We also assume that $\tau c_f(0) > c_d$ and $\tau c_f(1) < c_d$ so that there exists a cutoff intermediate that is not imported that is solution to

$$\tau c_f(m) < c_d \tag{20}$$

It follows that the marginal cost to produce the composite intermediate input with one unit of quality q_{iM} satisfies:

$$\widetilde{P}_{iM}(\tau) = \left(m^* c_d + \tau \int_{m^*}^{1} c_f(m) dm\right) \tag{21}$$

Meanwhile, the marginal cost for one unit of effect e_v is $\frac{1}{\kappa_v}$. Minimizing the production cost implies that the marginal cost of producing a variety of final good with quality q by a firm with productivity φ is $\frac{1}{\varphi}\left(\frac{1}{\kappa_v}\right)^{1-\mu_i}\left(\widetilde{P}_{iM}(\tau)\right)^{\mu_i} g(q)$. Hence, the payment for workers, domestic inputs and foreign intermediate input are:

$$\begin{aligned}
w(q) &= (1-\mu_i)\left[\frac{1}{\varphi}\left(\frac{1}{\kappa_v}\right)^{1-\mu_i}\left(\widetilde{P}_{iM}(\tau)\right)^{\mu_i}\right]g(q) \\
p_d g(q) &= \frac{c_d}{\widetilde{P}_{iM}(\tau)}\mu_i\left[\frac{1}{\varphi}\left(\frac{1}{\kappa_v}\right)^{1-\mu_i}\left(\widetilde{P}_{iM}(\tau)\right)^{\mu_i}\right]g(q) \\
\tau p_f(m)\, g(q) &= \frac{\tau c_f(m)}{\widetilde{P}_{iM}(\tau)}\mu_i\left[\frac{1}{\varphi}\left(\frac{1}{\kappa_v}\right)^{1-\mu_i}\left(\widetilde{P}_{iM}(\tau)\right)^{\mu_i}\right]g(q)
\end{aligned}$$

which provide the microfoundation for their functions in our model.

C Quantity-Based Production Function Estimation

We rewrite production function as

$$q_{ft} = \beta_l l_{ft} + \beta_k k_{ft} + \beta_m m_{ft} + \omega_{ft} + \varepsilon_{ft} \tag{22}$$

where l_{ft}, k_{ft}, m_{ft} is the vector of (log) physical inputs: labor, capital and materials, β_l, β_k and β_m are the production function coefficients to be estimated; ω_{ft} is firm-specific productivity; and ε_{ft} is an i.i.d. error term.

We use the merged firm-level data, built upon the NBSC annual survey of manufacturing firms and another dataset from NBSC that contains physical quantity output of firms' main products during the same sample period in estimating physical TFP. Although this quantity output database provides the output quantity at 5-digit CPC level for each firm, we only have information on production inputs (e.g., employment, capital and material) at firm-level. As a result, we focus on single-product firms based on this merged sample.

Now this new sample provides the physical quantity of output q_{ft} and the information on employment, which allows us to measure labor input l_{ft} in physical quantity. However, capital k_{ft} and material m_{ft} inputs are only available in value terms; specifically, we use the value of fixed assets as a measure of k_{ft} and the total value of intermediate materials as a measure of m_{ft}. To back out the physical quantity of k_{ft} and m_{ft}, we deflate these values with the sector-specific price indices provided by Brandt, Van Biesebroeck and Zhang (2012). As a result, the true estimation specification of equation (22) is:

$$q_{ft} = \beta_l l_{ft} + \beta_k \widetilde{k}_{ft} + \beta_m \widetilde{m}_{ft} - \left(\beta_k w^k_{ft} + \beta_m w^m_{ft}\right) + \omega_{ft} + \varepsilon_{ft} \tag{23}$$

where $\widetilde{k}_{ft}, \widetilde{m}_{ft}$ denote the (observed) vector of deflated capital and material inputs, deflated by a sector-specific price index; w^x_{ft} denotes the deviation of the unoberserved (log) firm-specific input price from the (log) industry-wide input price index. Hence, consistent estimation requires the proper control for unobserved firm productivity ω_{ft} and the omitted firm-specific input price $B_t\left(w^k_{ft}, w^m_{ft}, \beta_k, \beta_m\right) = -\left(\beta_k w^k_{ft} + \beta_m w^m_{ft}\right)$.

To control for omitted firm-specific input prices, we follow De Loecker et al. (forthcoming) and Lu and Yu (2015) by assuming that firm-specific input prices ω_{ft} are a function of output price (p_{ft}), market share (ms_{ft}), and exporter status (e_{ft}), i.e., $w^x_{ft} = w_t\left(p_{ft}, ms_{ft}, e_{ft}\right)$ for $x = k$ or m. As a results, B_{ft} becomes $B\left(\left(p_{ft}, ms_{ft}, e_{ft}\right), \delta\right)$, where δ depends on the parameters in $w_t\left(\cdot\right)$. To proxy ω_{ft}, Levinsohn and Petrin (2003) assume that $\widetilde{m}_{ft} = m_t\left(\omega_{ft}, l_{ft}, \widetilde{k}_{it}, \mathbf{Z}_{ft}\right)$, where $\mathbf{Z}_{ft}$ is a vector of controls including output price (p_{ft}), market share (ms_{ft}), and exporter status (e_{ft}), input tariff (τ^{input}_{ft}), output tariff (τ^{output}_{ft}), product dummies and region dummies.

In the first stage, we estimate the following equation:

$$q_{ft} = \phi_t\left(l_{ft}, \widetilde{k}_{it}, \widetilde{m}_{ft}, \mathbf{Z}_{ft}\right) + \varepsilon_{ft}.$$

We approximate the function with a third-order polynomial in all its elements, with the exception of product dummies and region dummies. We add the product dummies and region dummies linearly and yields an estimate of predicted output $\widehat{\phi}_{ft}$ by getting rid of unanticipated shocks and/or measurement error ε_{ft}. One can then express productivity ω_{ft} as a function of data and parameters. In particular, we have:

$$\omega_{ft} = \widehat{\phi}_{ft} - \beta_l l_{ft} - \beta_k \widetilde{k}_{ft} - \beta_m \widetilde{m}_{ft} - B\left(\left(p_{ft}, ms_{ft}, e_{ft}\right), \delta\right)$$

Meanwhile, to recover the parameter $\beta_l, \beta_k, \beta_m$ and parameter vector δ in the second stage, we consider the following law of motion for productivity:

$$\omega_{ft} = g\left(\omega_{ft-1}, \tau^{input}_{ft-1}, \tau^{input}_{ft-1}, e_{ft-1}\right) + \xi_{ft}$$

We form moments based on the innovation in the productivity shock ξ_{ft}, which satisfies:

$$\xi_{ft} = \omega_{ft} - E\left(\omega_{ft} | \omega_{ft-1}, \tau^{input}_{ft-1}, \tau^{input}_{ft-1}, e_{ft-1}\right)$$

The moments that identify the parameters are:

$$E\left(\xi_{ft}\mathbf{Y}_{ft}\right) = 0$$

where $\mathbf{Y}_{ft}$ contains lagged labor, current capital, lag materials, as well as lag output prices, lagged market shares, lagged input/output tariff, lagged export status, and their appropriate interactions of inputs. Productivity is given by $\omega_{ft} = \widehat{\phi}_{ft} - \beta_l l_{ft} - \beta_k \widetilde{k}_{ft} - \beta_m \widetilde{m}_{ft} - B\left(\left(p_{ft}, ms_{ft}, e_{ft}\right), \delta\right)$.

D Supplementary Discussions

D.1 Robustness with Alternative Measures of Productivity and Firm Size

Table A.1: Robustness: Results with Alternative Measures of Productivity and Firm Size

	Dependent Variable: $\Delta \ln(price)$					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Using Value Added per Worker						
ΔDuty	-2.724***	-2.958***	-2.944***	-3.271***	0.388	0.912
	(0.745)	(0.966)	(0.866)	(1.187)	(0.991)	(1.086)
ΔDuty × ln(Value Added per Worker)	0.649***	0.630***	0.717***	0.703**	0.031	-0.037
	(0.174)	(0.223)	(0.205)	(0.284)	(0.181)	(0.199)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.007	0.007	0.007	0.008	0.005	0.005
Panel B: Using Total Sales						
ΔDuty	-3.473***	-4.646***	-3.746***	-5.277***	2.060	3.522*
	(0.993)	(1.574)	(1.171)	(1.937)	(1.926)	(2.020)
ΔDuty × ln(Total Sales)	0.292***	0.371***	0.317***	0.422**	-0.124	-0.220
	(0.087)	(0.142)	(0.106)	(0.180)	(0.141)	(0.146)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.004	0.005	0.004	0.005	0.009	0.010
Panel C: Using Total Employment Payments						
ΔDuty	-2.438**	-2.573	-2.701**	-3.053	1.316	3.064
	(1.017)	(1.647)	(1.159)	(1.856)	(2.126)	(2.416)
ΔDuty × ln(Total Employment Payments)	0.237**	0.239	0.258*	0.275	-0.090	-0.272
	(0.119)	(0.198)	(0.137)	(0.224)	(0.227)	(0.264)
Observation	16673	8846	14813	7699	1860	1147
R-square	0.003	0.003	0.004	0.004	0.007	0.009
Panels A, B and C:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment.

Table A.2: Results Using Instrumental Variable Estimation

	Instrumental Variable Estimation					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: instrumented by $Duty_{1997}$						
ΔDuty	-3.289***	-2.689***	-3.602***	-3.180***	-0.075	0.518
	(0.660)	(0.901)	(0.736)	(1.059)	(1.467)	(1.534)
ΔDuty × ln(TFP)	0.662***	0.486***	0.658***	0.480**	0.319	0.169
	(0.138)	(0.184)	(0.154)	(0.220)	(0.357)	(0.358)
Kleibergen-Paap rk LM χ^2 statistic	606.391	272.258	1319.881	784.757	38.486	12.526
Kleibergen-Paap rk Wald F statistic	828.463	420.565	983.191	639.515	174.685	48.582
Observation	16907	8971	15018	7799	1889	1172
R-square	0.017	0.019	0.017	0.019	0.052	0.066
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
Panel B: instrumented by $Duty_{2001}$						
ΔDuty	-2.972***	-2.297***	-3.114***	-2.596***	-0.292	0.498
	(0.611)	(0.830)	(0.681)	(0.979)	(1.377)	(1.466)
ΔDuty × ln(TFP)	0.609***	0.458***	0.600***	0.458**	0.287	0.125
	(0.129)	(0.172)	(0.145)	(0.207)	(0.299)	(0.308)
Kleibergen-Paap rk LM χ^2 statistic	282.798	160.806	222.205	124.279	154.251	29.792
Kleibergen-Paap rk Wald F statistic	1084.806	669.492	896.163	554.004	402.790	103.083
Observation	16907	8971	15018	7799	1889	1172
R-square	0.017	0.019	0.017	0.020	0.056	0.067
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000
Panels A and B:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Industry Fixed Effect	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected in parentheses. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

Table A.3: Robustness: Results Using the Whole Customs Data

	Dependent variable: Δln(price)					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-0.949	-1.692***	-1.262*	-1.964***	0.911	-0.292
	(0.639)	(0.613)	(0.763)	(0.722)	(1.422)	(0.972)
ΔDuty $\times$ ln(export value)	0.063	0.107**	0.078	0.124**	-0.035	0.021
	(0.044)	(0.043)	(0.054)	(0.050)	(0.088)	(0.064)
Industry Fixed Effect	yes	yes	yes	yes	yes	yes
Observation	56282	36785	49375	32074	6907	4711
R-square	0.010	0.008	0.008	0.007	0.018	0.017

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term and the changes between 2001 and 2006 in TFP. Industry fixed effect is computed at the HS2 product level.

Table A.4: Change in Export Prices vs. Initial Productivity based on Whole Customs Data

	Differentiated goods		Homogeneous goods	
	(1)	(2)	(3)	(4)
	≤50th	>50th	≤50th	>50th
Change in Export Price (HS6-Country):				
Per Firm-product-country, median	11.88%	10.21%	-2.69%	-0.20%
Per Firm-product-country, mean	17.59%	13.75%	-2.24%	3.18%
Change in Export Price (HS6):				
Per Firm-product, median	15.12%	12.28%	-0.17%	2.37%
Per Firm-product, mean	20.02%	16.05%	3.16%	8.87%

Notes: ≤50th indicates the firms associated with lower initial productivity (i.e., the bottom 50th percentile); >50th indicates the firms associated with higher initial productivity (i.e., the top 50th percentile).

Table A.5: Robustness: Results Using Processing Trade Sample

	Dependent variable: Δln(price)					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-0.540	0.306	-0.509	0.223	-0.374	3.613**
	(0.704)	(0.731)	(0.741)	(0.779)	(1.425)	(1.505)
ΔDuty × ln(TFP)	0.055	-0.053	0.045	-0.039	0.138	-0.596**
	(0.155)	(0.158)	(0.164)	(0.171)	(0.268)	(0.274)
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Industry Fixed Effect	yes	yes	yes	yes	yes	yes
Observation	14596	6179	13784	5834	812	345
R-square	0.026	0.015	0.025	0.013	0.109	0.164

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses.Dependent variable in specifications (1),(3),(5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2),(4),(6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at the CIC 2-digit industry level.

Table A.6: Sensitivity to Other Mechanisms

	Dependent Variable: Δln(price)								
	Whole Sample			Differentiated Goods			Homogeneous Goods		
	Δln(p_{fhc})		Δln(p_{fh})	Δln(p_{fhc})		Δln(p_{fh})	Δln(p_{fhc})		Δln(p_{fh})
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	uncertainty	exchange rate		uncertainty	exchange rate		uncertainty	exchange rate	
ΔDuty	-2.176***	-1.189**	-1.628**	-2.333***	-1.324**	-1.988**	-0.459	-0.861	0.795
	(0.739)	(0.530)	(0.662)	(0.862)	(0.594)	(0.804)	(1.130)	(1.010)	(1.111)
ΔDuty × ln(TFP)	0.462***	0.261**	0.288**	0.494***	0.302**	0.366**	0.150	0.150	-0.131
	(0.158)	(0.119)	(0.142)	(0.189)	(0.135)	(0.179)	(0.209)	(0.183)	(0.179)
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
Industry Fixed Effect	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observation	15086	18809	9253	13352	16468	7906	1734	2341	1347
R-square	0.020	0.007	0.007	0.021	0.006	0.007	0.050	0.038	0.037

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses.Dependent variable in specifications (1), (2), (4), (5), (7), and (8) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (3), (6), and (9) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

Table A.7: Effect of Tariff Reductions on Quality

	Dependent Variable: the change in effective quality $\Delta \ln(\hat{q}_{fhc})$								
	Whole Sample			Differentiated Goods			Homogeneous Goods		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔDuty	-5.585**	-29.729***	-20.113**	-6.575**	-31.679***	-21.336**	4.857	-2.060	-1.049
	(2.389)	(8.059)	(8.060)	(2.660)	(9.091)	(9.430)	(3.903)	(10.678)	(11.061)
ΔDuty $\times$ ln(TFP)		5.498***	3.820**		5.819***	3.909**		1.377	1.035
		(1.637)	(1.655)		(1.896)	(1.991)		(1.950)	(1.945)
Firm-level Controls	no	no	yes	no	no	yes	no	no	yes
Industry-level Competition Control	no	no	yes	no	no	yes	no	no	yes
Industry fixed effect	no	no	yes	no	no	yes	no	no	yes
Observation	16907	16907	16907	15018	15018	15018	1889	1889	1889
R-square	0.001	0.003	0.018	0.001	0.003	0.017	0.001	0.001	0.068

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable is the (log) effective quality change at the firm-HS6-country level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

E More Tables (Online Only)

Table A.8: Regressions with Separate Sample

	Dependent Variable: $\Delta \ln(price)$					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: firm-product-country level						
ΔDuty	-0.498	-0.215	-0.564	-0.334	0.173	0.654
	(0.322)	(0.246)	(0.360)	(0.283)	(0.599)	(0.467)
Observation	8468	8439	7608	7410	860	1029
R-square	0.017	0.023	0.016	0.025	0.062	0.097
Panel B: firm-product level						
ΔDuty	-0.566*	-0.249	-0.700*	-0.567	0.306	0.775
	(0.327)	(0.291)	(0.384)	(0.352)	(0.568)	(0.597)
Observation	4488	4483	3970	3829	518	654
R-square	0.019	0.028	0.019	0.030	0.073	0.123
Panels A and B:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Columns (1), (3), and (5) is for firms with low initial productivity; columns (2), (4), and (6) is for firms with high initial productivity. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment.

Table A.9: Impact of tariff reductions on export prices with different-period difference

	Dependent Variable: $\Delta \ln(price)$								
	Whole Sample			Differentiated Goods			Homogeneous Goods		
	2-year	3-year	4-year	2-year	3-year	4-year	2-year	3-year	4-year
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: dependent variable $= \Delta \log(p_{fhc})$									
ΔDuty	-0.966**	-1.196**	-1.486**	-1.073**	-1.419**	-1.452**	-0.185	0.048	-1.495
	(0.397)	(0.495)	(0.602)	(0.436)	(0.559)	(0.646)	(0.822)	(0.805)	(1.225)
ΔDuty × ln(TFP)	0.191**	0.261**	0.303**	0.213**	0.313**	0.291**	0.042	0.008	0.369
	(0.084)	(0.112)	(0.134)	(0.092)	(0.128)	(0.145)	(0.161)	(0.152)	(0.253)
Observation	158495	79736	37351	140227	70389	33041	18268	9347	4310
R-square	0.004	0.006	0.010	0.003	0.005	0.008	0.008	0.021	0.036
Panel B: dependent variable $= \Delta \log(p_{fh})$									
ΔDuty	-1.876***	-1.378**	-1.875**	-2.162***	-1.746**	-1.961**	-0.846	1.073	-0.590
	(0.540)	(0.588)	(0.800)	(0.655)	(0.685)	(0.896)	(0.633)	(1.004)	(1.305)
ΔDuty × ln(TFP)	0.381***	0.263**	0.361**	0.452***	0.324**	0.359*	0.139	-0.132	0.219
	(0.113)	(0.130)	(0.174)	(0.139)	(0.157)	(0.196)	(0.116)	(0.183)	(0.255)
Observation	68983	37175	18455	59787	32088	15925	9196	5087	2530
R-square	0.003	0.006	0.011	0.003	0.005	0.009	0.006	0.018	0.035
Panels A and B:									
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
Industry Fixed Effect	yes	yes	yes	yes	yes	yes	yes	yes	yes

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors corrected for clustering at the firm level in parentheses. Columns (1), (4),(7) correspond to 2-year difference; columns (2), (5), (8) correspond to 3-year difference; columns (3), (6), (9) correspond to 4-year difference. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.

Table A.10: Robustness: Weighted Regression Results

	Dependent Variable: $\Delta \ln(price)$					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Weighted by No. of Observations in 2-digit CIC Industry						
ΔDuty	-2.887***	-3.539***	-3.011***	-3.819***	0.298	2.322
	(0.815)	(1.180)	(0.885)	(1.295)	(1.644)	(1.592)
ΔDuty × ln(TFP)	0.528***	0.569**	0.538***	0.591**	0.051	-0.300
	(0.168)	(0.249)	(0.187)	(0.282)	(0.298)	(0.268)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.018	0.021	0.017	0.022	0.048	0.055
Panel B: Weighted by No. of Observations in Each Firm						
ΔDuty	-3.297***	-4.647***	-3.184***	-4.835***	-1.256	-1.066
	(1.054)	(1.444)	(1.121)	(1.590)	(2.016)	(2.324)
ΔDuty × ln(TFP)	0.616***	0.847***	0.563**	0.838**	0.531	0.465
	(0.220)	(0.302)	(0.238)	(0.330)	(0.406)	(0.477)
Observation	16907	8971	15018	7799	1889	1172
R-square	0.016	0.017	0.017	0.017	0.152	0.107
Panels A and B:						
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable in specifications (1), (3), and (5) is the (log) price change at the firm-HS6-country level; dependent variable in specifications (2), (4), and (6) is the (log) price change at the firm-HS6 product level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment.

Table A.11: Results with Controlling for Markup

	Dependent Variable: $\Delta \ln(price)$					
	Whole Sample		Differentiated Goods		Homogeneous Goods	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔDuty	-2.432***	-2.200***	-2.588***	-2.220**	-0.466	-4.634
	(0.697)	(0.771)	(0.803)	(0.892)	(1.179)	(10.600)
ΔDuty × ln(TFP)	0.499***	0.446***	0.523***	0.444**	0.180	0.900
	(0.149)	(0.165)	(0.176)	(0.194)	(0.229)	(1.862)
ΔMarket share	0.124***	1.145	0.131***	1.094	0.047	3.104
	(0.025)	(1.134)	(0.027)	(0.959)	(0.046)	(7.462)
Firm-level Controls	yes	yes	yes	yes	yes	yes
Industry-level Competition Control	yes	yes	yes	yes	yes	yes
Industry fixed effect	yes	yes	yes	yes	yes	yes
Observation	16907	16907	15018	15018	1889	1889
R-square	0.019	0.017	0.020	0.017	0.059	0.058
Kleibergen-Paap rk LM χ^2 statistic		3.56		4.82		0.26
Kleibergen-Paap rk Wald F statistic		3.52		4.79		0.25

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1. Robust standard errors corrected for clustering at the firm level in parentheses. Dependent variable is the (log) price change at the firm-HS6-country level. All regressions include a constant term, firm-level controls, and industry-level competition control. Industry-level competition control refers to the change of Herfindahl index. Firm-level controls include the changes between 2001 and 2006 in the following variables: TFP, capital intensity, average wage, and total employment. Industry fixed effect is computed at 2-digit CIC industry level.