Tariff Pass-through, Firm Heterogeneity and Product Quality*

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Abstract

Previous studies on tariff pass-through were constrained at the industry level. This paper explores tariff pass-through at the firm level, and investigates how it depends on firm heterogeneity in productivity and product differentiation in quality. Using an extended version of the Melitz and Ottaviano (2008) model, I show that exporting firms adjust both their markups and product quality in response to a tariff change, which leads to a self-adjustment of their tariff-exclusive prices and in turn an incomplete tariff pass-through; Moreover, the price self-adjustment elasticity (tariff absorption elasticity) negatively depends on firm productivity for "quality goods", with high scope for quality differentiation, but positively depends on firm productivity for "cost goods", with low scope for quality differentiation. Using the U.S. transaction-level export data and plant-level manufacturing data, I find evidence for these predictions: In response to a tariff reduction of 10 percentage points, firms on average raise their tariff-exclusive prices by 8.7 percent; All products as a whole could be described as "quality goods", and the price increase is higher for low productivity firms (12.7 percent) and lower for high productivity firms (4.4 percent); Dividing all products into "cost goods" and "quality goods" also results in estimates broadly consistent with model predictions, especially for "quality goods".

Key Words: Tariff Pass-through, Firm Heterogeneity, Product Quality, Markups
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1. Introduction

This paper explores tariff pass-through at the firm level, and investigates how it depends on firm heterogeneity in productivity and product differentiation in quality. Using an extended version of the Melitz and Ottaviano (2008) model, I show that exporting firms adjust both their markups and product quality in response to a tariff change, which leads to a self-adjustment of their tariff-exclusive prices and in turn an incomplete tariff pass-through; Moreover, the price self-adjustment elasticity (tariff absorption elasticity) negatively depends on firm productivity for "quality goods", with high scope for quality differentiation, but positively depends on firm productivity for "cost goods", with low scope for quality differentiation. Using the U.S. transaction-level export data and plant-level manufacturing data, I find evidence for these predictions.

This paper derives its motivation from the literature in two areas: the incompleteness of tariff pass-through, and the heterogeneous firm models of international trade. The incompleteness of tariff pass-through is the source of terms-of-trade effect of trade policies. It says that when a country raises its tariff rate on a product, foreign exporting firms which sell in its market may absorb part of the tariff change by lowering their exporting prices[1]. Thus the tariff-inclusive consumer prices increase by a magnitude less than the tariff increase, and the impact of tariff change on market demand is mitigated. Tariff increase improves terms-of-trade for the home country and worsens the terms-of-trade of its trading partners. This terms-of-trade effect is the basis for the optimal tariff argument, from Edgeworth (1894) to Broda, Limao and Weinstein (2008), Bagwell and Staiger (2009), and Ludema and Mayda (2010): the lower is the export supply elasticity that a country faces, the higher is the optimal tariff that the country could and would set to exploit the terms-of-trade gain.

There have been several empirical studies on the incompleteness of tariff pass-through. Feenstra (1989) finds that the US tariff imposition in 1980s against the imports of Japanese automobiles led to a reduction of the exporting prices of the Japanese autos to the US. Kreinin (1961) finds that more than two-thirds of US tariff reductions in Geneva

[1] For this reason I also refer to incomplete tariff pass-through as "tariff absorption" hereafter.

Round were passed on as higher prices to countries exporting to the US; Mallick and Marques (2007) find similar qualitatively results for India's trade liberalization in 1990s.

However, all the existing studies on tariff pass-through were constrained at the industry level. That is, they study how the average price of all firms in an industry responds to a tariff change[2]. In these studies, it was not clear (1) whether the industry-level price response to tariff change is caused by the intra-industry reallocation between firms with different prices or the firm-level price change, and (2) if it is caused by the firm-level price change, whether it is due to cost change or markup adjustment. Feenstra (1989) controls for the marginal cost of production in his estimation of the tariff pass-through elasticity. However, it is still not clear whether the industry-level price change is caused by firm-level markup adjustment or intra-industry reallocation.[3]

To investigate this, I turn to the second literature relevant to this paper —- heterogeneous firm models of international trade, since these models focus on the intra-industry reallocation of firms caused by changes in trade environment. Heterogeneous firm models were spurred by empirical studies, beginning with Bernard and Jensen (1995)[4], which use plant or firm-level data and show that exporting firms are on average larger and more productive than non-exporting firms. These models are characterized by firm heterogeneity in productivity, e.g., Melitz (2003) and Bernard, Eaton, Jensen, and Kortum (2003). Melitz (2003) shows the exposure to trade induces the more productive firms to enter the export market, some less productive firms produce only for domestic market, and the least productive firms to exit the market. Thus the exposure to trade leads to inter-firm reallocations towards more productive firms.

None of the heterogeneous firm models focuses directly on how firm heterogeneity impacts tariff pass-through, though most of them have some implications for this. The first-generation heterogeneous firm models assume constant marginal cost as well as CES

[2]This is partly due to the data availability constraints faced by the researchers.

[3]In another paper, Feenstra and Weinstein (2010) estimate the magnitude of markup reduction and welfare gain of the US caused by globalization, but the study focuses on the markup reduction of domestic firms in the liberalizing country instead of the markup adjustment of foreign firms exporting to the liberalizing country, and hence it is not directly related to tariff pass-through. In addition, their empirical study is also constrained at the industry level.

[4]Others include Roberts and Tybout (1997), Bernard and Jensen (1999), Bernard, Jensen, Redding, and Schott (2007), etc.

utility, with the latter implying constant markups. With constant marginal cost and markups, firms do not have any room for price adjustment, and thus the observed incomplete tariff pass-through at the industry level must be completely due to the intra-industry reallocation between firms with different prices. For intra-industry reallocation to explain incomplete tariff pass-through, it must be, for the case of tariff reduction, that the new entrants caused by tariff reduction, which are less productive than incumbents, should have higher-than-average prices. However, there is a large body of heterogeneous firm models that incorporate product quality into CES utility, such as Baldwin and Harrigan (2007), Kugler and Verhoogen (2008), Mandel (2008), and Gervais (2009), among others. These models predict that lower productivity firms could have lower-than-average prices since they produce lower quality goods than incumbents. The researchers also provide empirical evidence supporting this prediction. Therefore the first-generation heterogeneous firm models based on CES utility and constant markups are not convincing in explaining the incompleteness of tariff pass-through.

Given this consideration, I switch to the second-generation heterogeneous firm models, beginning with Melitz and Ottaviano (2008). These models feature linear demand and variable markups. With variable markups, firms could and will adjust their markups and hence their exporting prices when they face a tariff change, even if they have constant marginal cost. Therefore, the models attribute the incompleteness of tariff pass-through to the firm-level markup adjustment. Antoniades (2008) incorporates product quality into the Melitz and Ottaviano (2008) model. Given the empirical evidence supporting heterogeneous firm models with quality dimension, this model is a good starting point for analyzing tariff pass-through. My model is simlar to Antoniades (2008), but I assume that the quality-producing cost is quantity-dependent and destination-dependent, while in his model the quality-producing cost is quantity-invariant and destination-invariant. As will be seen in section 2, the assumption in this paper makes the model more coherent than Antoniades (2008) to guarantee a closed form solution to the model.

I use the model to show that when exporting firms face a tariff change, they will not only change their markups due to the linear demand structure, but also change their product quality, both of which lead to a self-adjustment of their tariff-exclusive prices and an incomplete tariff pass-through. Moreover, due to the linear demand structure, the absolute magnitude of the price self-adjustment (tariff absorption) is identical across firms exporting the same product but with various productivity. As a result, for "quality goods" with high scope for quality differentiation and a positive price-productivity schedule, the price self-adjustment elasticity (tariff absorption elasticity) is lower for high productivity firms since they have high initial prices; In contrast, for "cost goods" with low scope for quality differentiation and a negative price-productivity schedule, the price self-adjustment elasticity is higher for high productivity firms since they have low initial prices. In sum, the model predicts that tariff pass-through depends on both firm heterogeneity in productivity and product differentiation in quality.

In order to verify these predictions with empirical evidence, we need to use firm-level data on trade and productivity. I use the U.S. transaction-level export data and plant-level manufacturing data in late 1990s, which were collected by the U.S. Census Bureau. From the export data I construct firm-level export price changes over time for each exported product to each destination country, and explore how they depend on tariff changes of destination countries. From the manufacturing data I construct the firm-level productivity. Then I link them to the export data, and explore how export prices and tariff pass-through depend on firm productivity.

I find evidence supporting the predictions of the model. First, in response to a tariff reduction of 10 percentage points, firms on average raise their tariff-exclusive prices by 8.7 percent, which confirms the incompleteness of tariff pass-through at the firm level. Second, all products as a whole could be described as "quality goods", and the price increase is higher for low productivity firms (12.7 percent) and lower for high productivity firms (4.4 percent). Third, dividing all products into "cost goods" and "quality goods" according to various criteria (price-productivity schedule, R&D/sales ratio, etc.) also results in estimates broadly consistent with model predictions, especially for "quality goods".

To my knowledge, this is the first paper that (1) explores the incompleteness of tariff pass-through at the firm level, and (2) investigates the impact of firm productivity and product quality on tariff pass-through. These two are the main contributions of the paper to the tariff pass-through literature. The second one is also the main contribution of the paper to the literature on heterogeneous firm models in international trade.

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 contains the empirical strategies. Section 4 describes the dataset. Section 5 includes the estimation results. Section 6 concludes.

2. The Model

2.1. Conusmers and Demand

As mentioned in section 1, my model is based on Melitz and Ottaviano (2008) and Antoniades (2008). Consider a world consisting of a Home country (h) and a Foreign country (f), with consumers L^h and L^f in each country. Preferences are defined over a homogeneous good chosen as numeraire, and a continuum of horizontally-differentiated varieties indexed by $i \in \Omega$. Consumers in both countries share the same quasi-linear utility function as in Antoniades (2008):

$$U = q_0^c + \alpha \int_{i \in \Omega} (q_i^c + z_i) di - \frac{1}{2}\gamma \int_{i \in \Omega} (q_i^c - z_i)^2 di - \frac{1}{2}\eta \left(\int_{i \in \Omega} (q_i^c - \frac{1}{2} z_i) di \right)^2, \quad (1)$$

where q_0^c and q_i^c represent, respectively, the individual consumption levels of the numeraire good and variety i; z_i stands for the quality level of variety i, and thus indexes the vertical differentiation of the variety. If the quality level for all varieties is 0 ($z_i = 0$ for all i), then the utility function boils down to that in Melitz and Ottaviano (2008). The demand parameters α and η index the substitution pattern between the numeraire and the horizontally-differentiated varieties, while the parameter γ indexes the degree of horizontal differentiation between the varieties. They are all positive.

The utility function implies the following linear market demand for variety i in country $l \in \{h, f\}$:

$$q_i^l \equiv L^l q_i^c = \frac{\alpha L^l}{\eta N^l + \gamma} - \frac{L^l}{\gamma} p_i^l + \frac{\eta N^l L^l}{(\eta N^l + \gamma)\gamma} \bar{p}^l + L^l z_i^l - \frac{1}{2} \frac{\eta N^l L^l}{\eta N^l + \gamma} \bar{z}^l, \quad (2)$$

where p_i^l and z_i^l are, respectively, the price and quality of variety i in country l; N^l is the measure of varieties actually consumed in country l (with $q_i^l > 0$); $\bar{p^l} = \frac{1}{N}\int_{i\in\Omega^l} p_i^l di$ and $\bar{z^l} = \frac{1}{N}\int_{i\in\Omega^l} z_i^l di$ are the average price and quality (across both local and foreign firms selling in country l) of these consumed varieties, where $\Omega^l \subset \Omega$ is the subset of varieties that are consumed. The demand function implies: (1) The demand for variety i is negatively related to its own price but positively related to its own quality; (2) It is positively related to the average price of all varities and negatively related to the average quality of all varieties, and (3) All these relationships are linear.

2.2. Firms, Production and Export

Each firm in each country produces a differentiated variety and faces a fixed entry cost f_E, which is common across firms. Subsequent production of firm i incurrs the following total cost function:

$$TC_i = c_i q_i + b q_i z_i + \theta(z_i)^2. \tag{3}$$

where q_i and z_i are the quantity and quality of the variety that the firm produces. The first term on the righ hand side, $c_i q_i$, depends on the quantity but not the quality of output, and could be interpreted as "processing cost" of a firm. c_i is a firm-specific constant and $1/c_i$ indexes firm productivity. The second term, $b q_i z_i$, depends on both the quantity and the quality of the output, which captures the feature of "component upgrading cost" and "advertising cost" associated with quality upgrading. This type of cost can vary across sale destinations (home or foreign). It is absent in Antoniades (2008) but will turn to be important soon in this paper. The third term, $\theta(z_i)^2$, depends on the quality level of the output but fixed with respect to the quantity of output, which captures the feature of "R&D cost" for producing quality. This cost is invariant across sale destinations. The parameters b and θ are common across all firms producing different varieties of the same product, and thus they are product-specific and index the "toughness" of producing quality for a product. Firms learn about their productivity c only after making the irreversible investment f_E required for entry, but b and θ are common knowledge.

Consider a firm in the Home country h with productivity parameter c. The firm faces both domestic and foreign markets. Assume (1) the two markets are segmented, and (2) the firm chooses separate levels of product quality for the two markets. The purpose of making these two assumptions is to ensure a closed form solution to the model. The validty of the second assumption is based on the "component cost" and "advertising cost" associated with quality upgrading, which could vary across different markets[5]. These two assumptions, together with the assumption of constant marginal "processing cost" c, imply that the firm independently maximizes the profits earned from domestic and export sales:

$$\begin{aligned} \pi^{hh} =& p^{hh} q^{hh} - c q^{hh} - b q^{hh} z^{hh} - \theta (z^{hh})^2, \\ \pi^{hf} =& \frac{p^{hf}}{\tau^f} q^{hf} - c q^{hf} - b q^{hf} z^{hf} - \theta (z^{hf})^2, \end{aligned} \tag{4}$$

where p^{hh} and p^{hf} denote its prices in the domestic and foreign markets; q^{hh} and q^{hf} stand for the corresponding quantities sold in the two markets; $\tau^f > 1$ is the ad valorem gross tariff rate imposed by the foreign country. Note that the tariff-exclusive export price of the firm is $p^* = p^{hf}/\tau^f$.

Solutions to the profit maximization problems are:

$$\begin{aligned} p^{hh} =& \frac{1}{2}(c^{hh} + c) + \frac{\gamma + b}{2} z^{hh}, \\ p^{hf} =& \frac{\tau^f}{2}(c^{hf} + c) + \frac{\gamma + b}{2} z^{hf}, \\ z^{hh} =& \lambda^h (c^{hh} - c), \\ z^{hf} =& \tau^f \lambda^f (c^{hf} - c). \end{aligned} \tag{5}$$

where $c^{hh} = sup\{c : \pi^{hh} > 0\}$ and $c^{hf} = sup\{c : \pi^{hf} > 0\}$ are cost upper bounds for firms to earn positive profits from domestic and export sales; $\lambda^h = \frac{(\gamma - b)L^h}{4\gamma\theta + (b^2 + b - \gamma^2)L^h}$ and $\lambda^f = \frac{(\gamma - b)L^f}{4\gamma\theta + (b^2 + b - \gamma^2)L^f}$. It is easy to show that $c^{hf} = c^{ff}/\tau^f$. Assume that $\gamma - b > 0$, $4\gamma\theta + (b^2 + b - \gamma^2)L^h > 0$ and $4\gamma\theta + (b^2 + b - \gamma^2)L^f > 0$ to ensure z^{hh} and z^{hf} to be positive.

[5] Antoniades (2008) does not have this type of cost, and thus it is hard to justify the second assumption, which is essential to guarantee a closed form solution to the model

2.3. Equilibrium and Price Structure

The free entry condition implies that the expected profits from domestic and export sales should be equal to the fixed entry cost, f_E, that is,

$$\int_0^{c^{hh}} \pi^{hh} dG(c) + \int_0^{c^{hf}} \pi^{hf} dG(c) = f_E \tag{6}$$

where $G(c)$ is the distribution of the "processing cost" c. Assume that this cost has a Pareto distribution with parameter k and upper bound c_M: $G(c) = (c/c_M)^k$, where $c \in [0, c_M]$. Substituting this and (4)-(5) into (6), doing the same thing for the free-entry condition in the foreign country, and using $c^{hf} = c^{ff}/\tau^f$, we get the two cost bounds:

$$\begin{aligned} c^{hh} &= \left[\frac{\gamma\phi}{L^h[1+(\gamma-b)\lambda^h]} \frac{1-\rho^f\sigma^f}{[1-(\rho^f\sigma^f)(\rho^h\sigma^h)]} \right]^{\frac{1}{k+2}}, \\ c^{hf} &= \left[\frac{\gamma\phi}{L^f[1+(\gamma-b)\lambda^f]} \frac{1-\rho^h\sigma^h}{[1-(\rho^h\sigma^h)(\rho^f\sigma^f)]} \right]^{\frac{1}{k+2}} /\tau^f, \end{aligned} \tag{7}$$

where $\phi = 2(k+1)(k+2)c_M^k f_E$, $\rho^l = (\tau^l)^{-k}$, and $\sigma^l = \frac{[1+(\gamma-b)\lambda^l]^2}{[1+(\gamma-b)\lambda^j]^2}$, for $l, j \in \{h, f\}$ and $l \neq j$. Equations (5) and (7) determine the closed form solutions to the model.

It is very helpful to have a careful examination for the internal structure of the equilibrium export price. As mentioned before, the incompleteness of tariff pass-through is equivalent to "tariff absorption" of exporting firms, i.e., a self-adjustment of their tariff-exclusive prices. Since the export price data used in the empirical analysis is tariff-exclusive (see section 4), I will focus on the tariff-exclusive price of a firm:

$$\begin{aligned} p^* =& \frac{p^{hf}}{\tau^f} \\ =& \frac{1}{2}\left(c^{hf}+c\right) + \frac{(\gamma+b)}{2}\frac{z^{hf}}{\tau^f} \\ \equiv& p_q^* + p_z^* \\ =& \frac{1}{2}\left(c^{hf}+c\right) + \frac{(\gamma+b)\lambda^f}{2}\left(c^{hf}-c\right) \\ =& \frac{1+(\gamma+b)\lambda^f}{2}c^{hf} + \frac{1-(\gamma+b)\lambda^f}{2}c \\ =& \frac{4\gamma\theta + bL^f}{2[4\gamma\theta+(b^2+b-\gamma^2)L^f]}c^{hf} + \frac{4\gamma\theta+(2b^2+b-2\gamma^2)L^f}{2[4\gamma\theta+(b^2+b-\gamma^2)]L^f]}c. \end{aligned} \tag{8}$$

The first equality is the definition of the tariff-exclusive export price. The second equality shows that the price consists of two components: the first term, $\frac{1}{2}\left(c^{hf}+c\right)$, is derived from the production of the quantity of the variety; the second term, $\frac{(\gamma+b)}{2}\frac{z^{hf}}{\tau^{f}}$, is derived from the production of the quality of the variety. I refer to these two components as p_q^* and p_z^*, respectively —- as indicated by the third equality (equivalence).

The forth equality shows the relationship between these two components and firm productivity. The quantity component, $p_q^* = \frac{1}{2}\left(c^{hf}+c\right)$, is negatively related to firm productivity $(1/c)$, i.e.,

$$\frac{\partial p_q^*}{\partial(\frac{1}{c})} < 0. \tag{9}$$

I refer to this as the "cost effect": the higher is firm productivity, the lower is the marginal "processing cost", and hence the lower is the unit price. The quality component, $p_z^* = \frac{(\gamma+b)\lambda^f}{2}\left(c^{hf}-c\right)$, is positively related to firm productivity $(1/c)$, i.e.,

$$\frac{\partial p_z^*}{\partial(\frac{1}{c})} > 0. \tag{10}$$

I refer to this as the "quality effect": the higher is firm productivity, the higher is the product quality level that the firm will choose[6], and thus the higher is the quality-producing cost and the unit price.

The fifth and the sixth (the last) equalities describe the relationship between the overall price and firm productivity. From these two equalities we can easily get

$$\frac{\partial p^*}{\partial(\frac{1}{c})} < 0 \qquad \text{iff} \qquad 4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f > 0, \tag{11}$$

$$\frac{\partial p^*}{\partial(\frac{1}{c})} > 0 \qquad \text{iff} \qquad 4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f < 0. \tag{12}$$

The intuition is as follows. The condition $4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f > 0$ implies that the quality-producing toughness parameters for the product, θ and b, are relatively high; Thus the quality level chosen by all firms (producing different varieties of the same product) is

[6]From equations (5) we can easily see that $\frac{\partial z^{hh}}{\partial(\frac{1}{c})} > 0$ and $\frac{\partial z^{hf}}{\partial(\frac{1}{c})} > 0$.

relatively low[7], and the product has low scope for quality differentiation; As the result, the "cost effect" dominates the "quality effect", and hence the overall price is negatively related to firm productivity —- I refer to this type of products as "cost goods", as in Mandel (2008). In contrast, the condition $4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f < 0$ implies that the toughness of producing quality for the product is relatively low; Thus the quality level chosen by all firms is relatively high, and the product has high scope for quality differentiation; As the result, the "quality effect" dominates the "cost effect", and hence the overall price is positively related to firm productivity —- I refer to this type of products as "quality goods", as in Mandel (2008).

2.4. Tariff Absorption, Firm Productivity and Product Quality

Now I shall turn to explore how a tariff change impacts the tariff-exclusive price, p^*. The third and forth equalities in equation (8) imply that this impact can be decomposed into the impacts of the tariff change on the two components of the price. More specifically, this impact is

$$\begin{aligned}\frac{\partial p^*}{\partial \tau^f} =& \frac{\partial p_q^*}{\partial \tau^f} + \frac{\partial p_z^*}{\partial \tau^f} = \frac{1}{2}\frac{\partial c^{hf}}{\partial \tau^f} + \frac{[(\gamma+b)\lambda^f]}{2}\frac{\partial c^{hf}}{\partial \tau^f} \\ =& -\frac{4\gamma\theta + bL^f}{2[4\gamma\theta + (b^2 + b - \gamma^2)L^f]}\frac{1}{(\tau^f)^2}\left[\frac{\gamma\phi}{L^f(1+\gamma\lambda^f)}T\right]^{\frac{1}{k+2}}\left(\frac{k}{k+2}\Gamma + 1\right) < 0,\end{aligned} \tag{13}$$

in terms of the absolute magnitude, and

$$\begin{aligned}\Theta^* \equiv& \frac{\partial p^*}{\partial \tau^f}\frac{\tau^f}{p^*} \\ =& -\frac{\left[\frac{\gamma\phi}{L^f(1+\gamma\lambda^f)}T\right]^{\frac{1}{k+2}}\left(\frac{k}{k+2}\Gamma + 1\right)}{\left[\frac{\gamma\phi}{L^f(1+\gamma\lambda^f)}T\right]^{\frac{1}{k+2}} + \frac{[4\gamma\theta + (2b^2+b-2\gamma^2)L^f]}{4\gamma\theta + bL^f}\tau^f c} < 0,\end{aligned} \tag{14}$$

in terms of the relative magnitude, where $T = \frac{1-\rho^h\sigma^h}{1-(\rho^h\sigma^h)(\rho^f\sigma^f)}$ and $\Gamma = \frac{(\rho^h\sigma^h)(\rho^f\sigma^f)}{1-(\rho^h\sigma^h)(\rho^f\sigma^f)}$. These two inequalities states the incompleteness of tariff pass-through, i.e., "tariff absorption": the tariff-exclusive export price increases in response to a tariff reduction. Θ^* is the tariff

[7]From equations (5) we can see that the quality level is negatively related to the quality-producing toughness parameters, θ and b.

absorption elasticity.

There are three things worth to be pointed out. First, we can easily see that both the quantity component and the quality component of the tariff-exclusive export price increase in response to a tariff reduction, that is, $\frac{\partial p_q^*}{\partial \tau^f} < 0$ and $\frac{\partial p_z^*}{\partial \tau^f} < 0$. The increase of the quantity component of the price is essentially an increase in its markup, i.e., $\frac{\partial u_q}{\partial \tau^f} < 0$, where $u_q = p_q^* - c = \frac{1}{2}(c^{hf} - c)$, since the production cost c is fixed. This markup adjustment is possible because of the linearity of the demand structure. The increase of the quality component of the price is caused by the quality upgrading of the product in response to the tariff reduction, that is, $\frac{\partial z^{hf}}{\partial \tau^f} < 0$.[8] In sum, when exporting firms face a tariff reduction, they will not only increase their markups due to the linear demand structure, but also upgrade the quality level of their products. That is, they will transfer the cost advantage due to tariff reduction to higher markups and quality advantage. Thus the model shows that both markup adjustment and quality adjustment are sources of firm-level tariff absorption.

Second, it is easy to see that the absolute magnitude of the export price increase in response to a tariff reduction does not depend on firm productivity, i.e.,

$$\frac{\partial(\partial p^*/\partial \tau^f)}{\partial(\frac{1}{c})} = 0. \tag{15}$$

This is because that the export price, $p^* = \frac{1+(\gamma+b)\lambda^f}{2} c^{hf} + \frac{1-(\gamma+b)\lambda^f}{2} c$, consist of two additively separable components: the first one (c^{hf}) depends on the foreign tariff rate (τ^f) but not firm productivity ($1/c$), and the second one (c) depends on firm productivity but not the foreign tariff rate.[9] When the tariff rate changes, only the first component changes, and hence the change is independent of firm productivity.[10]

Third, since the original export price does depend on firm productivity (see (11)

[8]We can also show the following. (1) The increase of the quality component of the price caused by the quality upgrading is due to the increase of quality-producing cost, i.e., $\frac{\partial c_z}{\partial \tau^f} < 0$, where $c_z = [bq^{hf} z^{hf} + \theta (z^{hf})^2]/q^{hf}$ is the unit quality-producing cost. (2) However, the sign of the markup change associated with quality-upgrading, $\frac{\partial u_z}{\partial \tau^f}$, is ambiguous, where $u_z = p_z^* - c_z$. (3) High productivity firms with high initial quality will upgrade their quality less than low productivity firms, i.e., $\partial \left| \frac{\partial z^{hf}}{\partial \tau^f} \right| / \partial(\frac{1}{c}) < 0$.

[9]This characteristic is generated by the linearity of the market demand.

[10]Actually this analysis is also true for both the quantity and the quality components of the price.

and (12)), the relative magnitude of the export price increase, i.e., the tariff absorption elasticity, also depends on firm productivity. From (14) we can show that

$$\frac{\partial \Theta^*}{\partial(\frac{1}{c})} < 0 \qquad \text{iff} \qquad 4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f > 0 \qquad \text{(cost good)}, \tag{16}$$

$$\frac{\partial \Theta^*}{\partial(\frac{1}{c})} > 0 \qquad \text{iff} \qquad 4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f < 0 \quad \text{(quality good)}. \tag{17}$$

Note that the condition $4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f > 0$ implies that the product is a "cost good" (see (11)). For this type of product, the original export price is negatively related to firm productivity. Thus the relative magnitude of the export price increase, i.e., the tariff absorption elasticity, in terms of its absolute value, is positively related to firm productivity $(1/c)$[11]. In contrast, the condition $4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f < 0$ implies that the product is a "quality good" (see in (12)). For this type of product, the original export price is positively related to firm productivity. Thus the tariff absorption elasticity, in terms of its absolute value, is negatively related to firm productivity.

In sum, the impacts of firm productivity and product quality on price level and tariff absorption can be summarized as the following:

For cost goods:

$$\frac{\partial p^*}{\partial(\frac{1}{c})} < 0, \qquad \frac{\partial \Theta^*}{\partial(\frac{1}{c})} < 0.$$

For quality goods:

$$\frac{\partial p^*}{\partial(\frac{1}{c})} > 0, \qquad \frac{\partial \Theta^*}{\partial(\frac{1}{c})} > 0.$$

From equation (14) we can also derive the following conclusions about the impacts of market size L^f and initial tariff τ^f on tariff absorption elasticity:

For cost goods:

$$\frac{\partial \Theta^*}{\partial L^f} >< 0, \quad \frac{\partial \Theta^*}{\partial \tau^f} > 0. \tag{18}$$

For quality goods:

$$\frac{\partial \Theta^*}{\partial L^f} < 0, \quad \frac{\partial \Theta^*}{\partial \tau^f} >< 0. \tag{19}$$

[11]Notice the difference between the "negative" sign of the parital derivative and the "positive" word interpretation in terms of absolute value. Same for inequality (17) below.

In words, for cost goods, there is an ambiguous relationship between tariff absorption elasticity and the foreign market size, and a negative relationship between tariff absorption elasticity (in terms of its absolute value) and the initial foreign tariff rate; while for quality goods, there is a positive relationship between tariff absorption elasticity (in terms of its absolute value) and the foreign market size, and an ambiguous relationship between tariff absorption elasticity and the initial foreign tariff rate.

3. Empirical Strategies

Now I turn to the empirical side to test the predictions of the model on tariff pass-through. As mentioned before, since the export prices I will get from the trade data are tariff-exclusive, I will focus on exlporing how tariff changes impact the tariff-exclusive prices, i.e., tariff absorption, and how this impact depends on firm productivity, product quality and other factors.

The main predictions of the model are: (i) The firm-level tariff pass-through is incomplete, that is, the tariff-exclusive prices increase in response to a tariff reduction (see (13) and (14)). (ii) The absolute change of the tariff-exclusive prices does not depend on firm productivity, for both cost and quality goods (see (15)). (iii) The relationship between the relative change of the tariff-exclusive prices (tariff absorption elasticity) and firm productivity depends on whether the good is a "cost good" or "quality good" (see (16) and (17)). The model also have some predictions on how market size and the initial tariff rate of the destination country impact tariff absorption elasticity (see (18) and (19)). I test these predictions in two different ways.

On the one hand, I test these predictions by pooling all products in the sample.

First, I use the following specification to check whether the products, as a whole, are "cost goods" or "quality goods":

$$\begin{aligned} lnP_{ifct} = & \beta lnTFP_{ft} + \delta_{ict} + \mu_{ifct}. \\ & (- : \text{cost}) \\ & (+ : \text{quality}) \end{aligned} \tag{20}$$

where lnP_{ifct} denotes the log tariff-exclusive price[12] of product i exported by firm f to country c in period t, $lnTFP_{ft}$ represents the log total factor productivity of firm f in period t, δ_{ict} stands for a product-country-period fixed effect, and u_{ifct} is the error term. Coefficient β measures how export prices are related to firm productivity: if β is negative, then the products, as a whole, are "cost goods" (see (11)); if β is positive, then the products, as a whole, are "quality goods" (see (12)).

Second, I use the following specification to check whether the absolute change of the export price in response to the tariff change depends on firm productivity or not:

$$\begin{aligned}\Delta P_{ifct} = &\underset{(-)}{\beta_1}\Delta\tau_{ict} + \beta_2 lnTFP_{f(t-1)} + \underset{(0)}{\beta_{12}}[\Delta\tau_{ict} \times lnTFP_{f(t-1)}] + FE + \mu_{ifct},\end{aligned} \tag{21}$$

where ΔP_{ifct} denotes the absolute change of the tariff-exclusive price of product i exported by firm f to country c from period $t-1$ to period t, $\Delta\tau_{ict}$ is tariff change of country c on product i from period $t-1$ to period t, $TFP_{f(t-1)}$ is the TFP of firm f in the base year $t-1$, and FE stands for various fixed effects. Coefficient β_1 measures the absolute change of the tariff-exclusive price of a benchmark firm (with $lnTFP_{f(t-1)} = 0$) in response to the tariff change. This coefficient should be negative according to (13); however, since the absolute magnitudes of export price changes for different products are not comparable, the magnitude of β_1 is meaningless. The coefficient of the interaction term between tariff change and firm TFP, β_{12}, measures how firm productivity impacts the absolute change of the export price in response to the tariff change. This coefficient should be 0 (that is, insignificant) according to (15). The separate TFP term is added in this specification in case firm productivity (or cost) has a direct effect on price change, but the model does not have a prediction about the sign of this direct effect.

Third, I use the following regression to estimate the tariff absorption elasticity:

$$\Delta lnP_{ifct} = \underset{(-)}{\beta}\Delta ln(1+\tau_{ict}) + FE + \mu_{ifct}, \tag{22}$$

[12]Note that throughout the empirical part, all prices are tariff-exclusive prices, which correspond to p^* in the theoretical part.

Notice that we now have logs for both the price change and the tariff change. Thus coefficient β measures the percent change of tariff-exclusive prices in response to percent change of tariff rates, that is, it measures tariff absorption elasticity. It should be negative according to (14). Also notice that we have gross tariff rate $(1+\tau_{ict})$ on the right hand side since that is the tariff rate in the theoretical model[13].

Next, I add firm productivity and its interaction with tariff change to estimate its direct effect on price change and its impact on tariff absorption:

$$
\begin{aligned}
\Delta lnP_{ifct} = & \beta_1 \underset{(-)}{\Delta ln(1+\tau_{ict})} + \beta_2 TFPH_{f(t-1)} + \underset{\substack{(-\,:\,\text{cost}) \\ (+\,:\,\text{quality})}}{\beta_{12}}[\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}] \\
& + \underset{(+)}{\beta_3} \Delta lnGDP_{ct} + \underset{(-)}{\beta_4} \Delta lnXR_{c(t-1)} + FE + \mu_{ifct},
\end{aligned} \tag{23}
$$

This specification is a counterpart of (21), but with two differences: (1) Here we have logs for both the price change and the tariff change; (2) Here we use a high TFP dummy $TFPH_{f(t-1)}$ to replace the level of firm TFP —- This dummy is set to 1 if the TFP of the exporting firm f in the base year $t-1$, $TFP_{f(t-1)}$, is higher than the average TFP of all firms exporting the same product i to the same destination country c, and 0 otherwise. Now the coefficient for the tariff change, β_1, measures the tariff absorption elasticity for low productivity firms. According to the model, it should be negative (by (14)). The coefficient for the interaction term between tariff change and the high TFP dummy, β_{12}, measures the difference between the tariff absorption elasticity for high productivity firms and the elasticity for low productivity firms. A negative β_{12} implies that high productivity firms have a higher tariff absorption elasticity (in absolute value) than low productivity firms, since the elasticity itself is negative, while a positive β_{12} implies that the opposite is true. According to the model, β_{12} should be negative for "cost goods" (by (16)), but positive for "quality goods" (by (17)).

[13] In specification (21) we have change of net tariff rate since that is equivalent to change of gross tariff rate, i.e., $\Delta\tau_{ict} = \Delta(1+\tau_{ict})$.

I also add two other control variables in the regression. The first one is change of log real GDP of the destination country, $\Delta lnGDP_{ct}$, which is used to control for the change of market demand. An increase of the market demand should push up export prices, and thus β_3 should be positive. The second one is change of log exchange rate (measured as units of foreign currency per U.S. dollar) one period before tariff change, $\Delta lnXR_{c(t-1)}$[14]. A dollar appreciation should cause U.S. exporting firms to lower their export prices denominated in U.S. dollars[15], and thus β_4 should be negative.

Finally, I add the market size and the initial tariff of the destination country, as well as their interaction with tariff change, to estimate their impacts on price change and tariff absorption:

$$
\begin{aligned}
\Delta lnP_{ifct} = & \underset{(-)}{\beta_1 \Delta ln(1+\tau_{ict})} + \beta_2 TFPH_{f(t-1)} + \underset{\substack{(-\,:\,\text{cost}) \\ (+\,:\,\text{quality})}}{\beta_{12}[\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}]} \\
& + \beta_3 lnGDP_{c(t-1)} + \underset{\substack{(+/-\,:\,\text{cost}) \\ (-\,:\,\text{quality})}}{\beta_{13}[\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}]} \\
& + \beta_4 ln(1+\tau_{ic(t-1)}) + \underset{\substack{(+\,:\,\text{cost}) \\ (+/-\,:\,\text{quality})}}{\beta_{14}[\Delta ln(1+\tau_{ict}) \times \ln(1+\tau_{ic(t-1)})]} \\
& + \underset{(+)}{\beta_5 \Delta lnGDP_{ct}} + \underset{(-)}{\beta_6 \Delta lnXR_{c(t-1)}} + FE + \mu_{ifct},
\end{aligned}
\tag{24}
$$

where $lnGDP_{c(t-1)}$ is log of GDP of country c in the base year, which measures its market size in the base year, and $\tau_{ic(t-1)}$ is the initial tariff rate in the base year. Again here coefficient β_1 should be negative according to the model. The coefficients for the three interaction terms, β_{12}, β_{13}, and β_{14}, measure the impact of firm productivity, market size,

[14] I use the lagged exchange rate changes because exchange rate changes typically have a lag effect, as shown in the exchange rate pass-through literature.

[15] As shown in the exchange rate pass-through literature.

and initial tariff rate on tariff absorption elasticity. Their signs are determined by (16)-(19). Coefficients β_2, β_3 and β_4 are direct effects of firm productivity, market size and initial tariff rate on price change, but the model does not have a prediction on their signs.

On the other hand, I also divide all products into two groups, "cost goods" and "quality goods", and run the regressions specified above separately for the two groups.

I use several different criteria to classify the products. The first criterion is the price-productivity schedule for each individual product. I run regression (20) separately for each product: if the coefficient β is negative, then I classify it as a "cost good"; otherwise, I classify it as a "quality good". This method may have some endogeneity problem: we use the price-productivity schedule to classify the products in the first stage, and then explore the relationship between price changes in response to tariff changes and firm productivity for each group of products in the second stage; the dependent variable and the independent variable in the first stage are related to those in the second stage, and thus there may exists some endogeneity between these two stages.

Due to this problem, I turn to the second method: use R&D investment for different industries to classify products. The model implies that quality upgrading is associated with R&D cost, component upgrading cost and advertising cost. The higher are those costs, the higher should be the scope for quality differentiation. As will be seen in section 4, R&D investment data are available for a wide range of industries, while the data for component upgrading cost and advertising cost are not. Thus I use the R&D investment for different industries to classify products: If a product is in an industry with a high R&D/sales ratio, then it is classified as a "cost good"; otherwise, it is classified as a "quality good".

The third method that I use to classify products is the Rauch classification. Rauch (1999) classifies products into commodities and differentiated goods. This classification is based on horizontal differentiation instead of vertical (quality) differentiation of products. However, there may exist some connection between these two types of differentiation. Inequality (11) says that a product is a "cost good" if $4\gamma\theta + (2b^2 + b - 2\gamma^2)L^f > 0$. Notice that this condition holds when the parameter γ is relatively small (since the negative term of γ is in the second order), which implies that the horizontal differentiation between varieties of the product is relatively small. Similarly, inequality (12) says that a product is a "quality good" if γ is relatively big, or the horizontal differentiation between varieties of the product is relatively big. Thus the level of quality (vertical) differentiation of a product is roughly positively related to the level of horizontal differentiation of the product. For this reason, I use the level of horizontal differentiation as a proxy of the level of quality differentiation: I treat commodities as "cost goods" and (horizontally) differentiated goods as "quality goods". As will be seen in section 5, treating commodities as "cost goods" may be not quite accurate, but treating (horizontally) differentiated goods as "quality goods" does make sense and result in estimates consistent with model predictions.

4. Data

There are four types of data used in the empirical analysis: trade data, tariff data, firm productivity data, and other data.

The trade data are used to compute firm-level export prices. The data is the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which was collected and assembled by the U.S. Census Bureau and the U.S. Customs for the period 1992-2005. The data links individual trade transactions to firms in the U.S. I will focus on the U.S. export transactions. For each export transaction in this period, the dataset records its product category (at HS10 level level), quantity, (tariff-exclusive) value, exporting firm, destination country, year and month in which the transaction occurs, etc. Bernard, Jensen and Schott (2005) provide a detailed description of the data. Before constructing export prices I clear the data in the following way. (1) Among all transactions, I first drop those with missing values in value, quantity, product category, export firm, destination country, or time. (2) Since measurement error in values or quantities causes measurement error for the constructed prices and leads to biased estimation, I remove the transactions (around 5 percent of the total) with extraordinary computed prices which are 20 times larger or smaller than the average price of all transactions in the same product-firm-country-year cell. (3) I also remove related party transactions (around 30 percent of the total), since the price behavior for related party transaction is quite different from arm's length transactions. For the rest of transactions, I construct firm-level prices (unit values) as $P_{ifct} = V_{ifct}/Q_{ifct} = \sum_{tr} V_{ifct,tr}/\sum_{tr} Q_{ifct,tr}$, where V_{ifct} and Q_{ifct} are the total value and quantity of product i (HS10) exported by firm f to country c in year t, and $V_{ifct,tr}$ and $Q_{ifct,tr}$ are the transaction-level value and quantity for the same product exported by the same firm to the same destination country in the same period. Thus the firm-level price P_{ifct} is the average transaction-level price weighted by transaction quantity. Since export values are tariff-exclusive, the constructed export prices are also tariff-exclusive and correspond to p^* in the theoretical part. Among all product-firm-country-year cells that I constructed export prices, I keep those surviving in two consecutive years. For these surviving cells I get price changes $\Delta P_{ifct} = P_{ifct} - P_{ifc(t-1)}$ or log price changes.

The tariff data contains the MFN tariff rates of various countries in the world. The data was collected by WITS (World Integrated Trade Solution) at the World Bank. They are annual data at the HS6 level, and thus are more aggregate than the trade data in both time and product dimensions. Since tariff rates are annual, the time dimension t of all variables in all regressions is also year. The actual tariff rate may vary across products within a same HS6 category. For each HS6 category, the data includes the maximum, minimum, and mean tariff rates of different products within the category. I only include HS6 categories within each there is no tariff variation (that is, the maximum, minimum and mean tariff rates are all identical), since only for these HS6 categories I can calculate meaningful tariff change over time, $\Delta\tau_{ict}$. I merge these tariff changes to price changes ΔP_{ifct}, and only keep product-firm-country-year cells for which there are both price change and tariff change information.

Firm productivity is constructed from the U.S. Census Manufacturing data (CMF) collected and maintained by the U.S. Census Bureau. For years ending with 2 or 7 (1987, 1992, 1997, etc.), the dataset records the production information (output, capital stocks, labor hours, energy and materials inputs, etc.) for all U.S. manufacturing establishments (plants). I use the 1997 CMF data for my empirical analysis, since most of the big tariff changes during the period 1992-2005 occurred around 1997.[16] From this data I construct plant-level TFP from the typical constant returns to scale index form:

$$lnTFP_{pt} = lnQ_{pt} - \phi_K lnK_{pt} - \phi_L lnL_{pt} - \phi_E lnE_{pt} - \phi_M lnM_{pt}$$

where TFP_{pt} is the TFP of plant p in period t, and Q, K, L, E and M represent plant-level output (value of shipment), capital stocks, labor hours, and energy and materials inputs. The firm-level productivity, TFP_{ft}, is computed as the average of the productivity of the plants within the same firm weighted by their output shares. Then I merge the firm-level TFPs in 1997 to the export price change and tariff change data from 1997 to 1998. This constitutes the benchmark sample for my empirical analysis.

In addition to the trade, tariff and firm productivity data, I also use GDP data to measure the market size, and use GDP change and exchange rate change as control variables. Both the GDP data and exchange rate data come from Penn World Table. Besides this, I also use industry-level R&D investment data to classify products into "cost goods" and "quality goods". The R&D investment data comes from the U.S National Science Foundation (NSF). The data contains U.S R&D investment at the 2-digit or 3-digit (for some industries) SIC (Standard Industry Classification) industry level. The R&D investment comes from three different sources: federal funds, company funds and other funds. The data on federal funds in many industries are not publically available for confidential consideration, but the data on company and other funds are available for almost all industries. The data contains the company and other R&D investment for each industry as a percent of the net sales of the same industry, the R&D/sales ratio. Since the R&D investment may have a lag effect in terms of its effectiveness, I average this ratio for each industry for 1995, 1996 and 1997, and use this average ratio as the indicator for R&D cost of the indusry in 1997, the base year in the benchmark 1997-1998 sample. I merge the data to the trade and tariff data by using a concordance between SIC classification and HS classification, which was created by Pierce and Schott (2009). Then I take the median of the ratio across all observations in the sample. If the ratio

[16] I plan to use 1992 and 2002 CMF data as well for robustness check.

for a product is lower than the median, it is classified as a "cost good"; otherwise, it is classified as a "quality good".

With all data at hand, I run the regressions in section 3 with two samples. The first sample is the full benchmark sample for 1997-1998. In the second sample, I only include countries with big tariff change for certain products during the period 1997-1998. More specifically, I only include the 38 countries for which there exists at least one HS6 industry with tariff change higher than 5 percentage points; but for each of these 38 countries, I keep all industries no matter whether they have big tariff change or not. The purpose of choosing this sample is to ensure that there are enough observations with big tariff changes to induce price changes and, at the same time, there are also enough observations with small tariff changes for the purpose of comparison.

People may wonder that whether my sample construction process will lead to selection bias, especially when I (1) restrict my analysis to HS6 industries within each there is no tariff variation, and (2) only include countries which have big tariff changes for certain products. To address this concern, I compare three samples: the first one is the 1997-1998 sample which contains all HS6 industries (I refer to this sample as "pre-sample"); the second one is the benchmark 1997-1998 sample which only contains HS6 industries within each there is no tariff variation ("benchmark sample"); the third one is the subsample that only contains the 38 countries which have big tariff changes in certain industries ("sub-sample"). Table 1 lists some summary statistics for these three samples, including number of industries (HS2 and HS6), products (HS10), exporting firms, and destination countries, as well as the total export value in the base year (TV_{t-1}) and summary statistics for the main variables used in the regressions.

The comparison between the first and the second sample shows that only half of all HS6 industries (2,005 out of 3,971) do not have tariff variation within each industry; because of this, the number of HS10 products and firms as well as the total export value in the second sample are much lower than (about half) those in the first sample. However, the number of HS2 industries and destination countries, as well as the mean and standard deviation of the main variables in the two samples are very close to each other, which shows that the second sample is quite representative for the first one. The comparison between the second and the third sample shows that even though the third sample only contains two thirds of the countries (38 v.s. 61) in the second sample, all the other indicators in the two samples are very close to each other, which shows that the third sample is quite representative for the second one. This is because that the 38 countries contained in the third sample, which are listed in table 2, not only include all the big trade partners of the U.S. (such as Canada, Mexico, European Union countries, Japan, China, etc.), but also include middle-size countries (such as Egypt, Turkey, Argentina, etc.) and small countries (such as Dominica, Salvador, Honduras, Ecuador, etc.).

Another observation from table 1 is the structure of tariff change. From the table we can see that, in all the three samples, observations with tariff reduction account for 43 to 53 percent of all observations, those without any tariff change account for 41 to 53 percent, and those with tariff increase only account for 4 to 6 percent. Thus most of the tariff changes are tariff reductions, and the regression results about tariff absorption in next section could be interpreted as the increases of the tariff-exclusive prices in response to tariff reductions.

5. Empirical Results

5.1. All Products Together

In this subsection, I present the regression results for all products as a whole, without dividing them into "cost goods" and "quality goods". I run the regressions specified before for two samples: the first one is the full benchmark sample for 1997-1998, and the second one is the subsample which only contains the 38 countries with big tariff change.

Table 3 contains the results for the full benchmark sample. Column 1 contains the result for specification (20), which is used to check the price-productivity schedule and the nature of products. Here I find a positive and significant relationship between export prices and firm productivity: a 10 percent increase of firm TFP leads to a 0.6 percent increase of the export price. Thus, all products as a whole could be described as "quality goods". Column 2 contains the result for specification (21), which is used to check whether firm productivity impacts the absolute magnitude of tariff absorption. Here I control for a product and a country fixed effect. The coefficient for the interaction term between tariff change and firm TFP is not significant. This indicates that firm productivity does not impact the absolute magnitude of tariff absorption, which is consistent with the model prediction.

Columns 3-4 are the results for specifications (22)-(23), which are used to estimate the overall tariff absorption elasticity and the impact of firm productivity on tariff absorption elasticity. In these two columns I do not include any fixed effect[17]. Column 3 shows that the overall tariff absorption elasticity is 0.09 but not significant. Column 4 shows that the tariff absorption elasticity for low productivity firms is 0.53 but not significant, neither. The elasticity for high productivity firms is significantly lower[18], which is consistent with the model prediction for "quality goods". However, here the tariff absorption elasticity for high productivity firms is actually a positive number ($-0.53 + 0.89 = 0.46$), which indicates that these firms do not absorb any tariff change and their tariff pass-through elasticity is actually higher than 1 (1+0.46=1.46). This is a little bit confusing.

To address this concern, as well as the insignificance of the overall tariff absorption elasticity and the elasticity for low productivity firms, I repeat regressions (22)-(23) in columns 5-6, but add a product fixed effect to control for unobserved product-specific shocks that impact the price change. Now the overall tariff absorption elasticity increases to 0.48 and becomes significant. The elasticity for low productivity firms is 0.89 and significant, and much lower for high productivity firms (0.05, since $-0.89+0.84 = -0.05$), which is still consistent with the model prediction for "quality goods". Moreover, now the elasticity for high productivity firms is a negative number ($-0.89 + 0.84 = -0.05$), which is in its normal range.

In columns 7-8 I repeat regressions (22)-(23), but add both a product fixed effect and a country fixed effect. The country fixed effect is used to control for unobserved

[17]Note that since the specifications that I use are first order differences, I have actually already differenced out all time-invariant fixed effects (including product, firm, country, product-firm, product-country, firm-country, and product-firm-country fixed effect) on price level (not on price change).

[18]As indicated before, a positive coefficient for the interaction term between tariff change and firm productivity, 0.89, indicates a negative relationship between tariff absorption elasticity and firm productivity, since the elasticity itself is negative.

country-specific shocks (such as exchange rate changes and demand changes) that impact the price change. Now the overall tariff absorption elasticity increases further to 0.87 and is significant. This implies that exporting firms increase their tariff-exclusive price by 8.7 percent in response to a tariff reduction of 10 percentage points. The elasticity for low productivity firms is 1.27 and significant. A tariff absorption elasticity higher than 1 implies that the tariff pass-through elasticity is actually negative ($1 - 1.27 = -0.27$): In response to a tariff reduction of 10 percent, low productivity firms increase their tariff-exclusive prices by 12.7 percent; as a result, the tariff-inclusive consumer prices actually increase by 2.7 percent instead of decreasing. This is known as "Metzler Paradox". Here the tariff-exclusive prices increase so much because the original product quality for these low productivity firms is low; when they face a tariff reduction, they upgrade their product quality by a significant magnitude, which leads to a high increase in their prices. Thus, quality upgrading provides a reasonable explanation for the "Metzler Paradox". On the other hand, the tariff absorption elasticity for high productivity firms is 0.44 ($-1.27 + 0.83 = -0.44$), which is much lower than that for low productivity firms. This is still consistent with the model prediction for "quality goods".

In column 9 I repeat regression (23) but adding other two control variables: changes of exchange rates and GDPs (which measures market demand) of the destination countries. Since these two variables are country specific, I drop the country fixed effect and only keep the product fixed effect in the regression. The estimates for these two controls are not significant, but including them in the regression changes the tariff absorption elasticities to 0.89 for low productivity firms and 0.05 ($-0.89 + 0.84 = -0.05$) for high productivity firms. The lower elasticity for higher productivity firms is still consistent with the model prediction for "quality goods".

Column 10 contains the results for specification (24), which is used to check the impacts of market size and initial tariff rate on tariff absorption elasticities. Here I add the GDP (measuring market size) of the destination country in the base year (1997) and the initial tariff rate, as well as their interaction with tariff change. The coefficients for these four variables show their direct impacts on price changes and their impacts on tariff absorption. The estimates show that none of these impacts is significant. Notice that in this specification the coefficient for the tariff change term (-4.96) measures the tariff absorption elasticity for low productivity firms ($TFPH = 0$) exporting to a country with a hypothesized GDP ($lnGDP = 0$) and a hypothesized tariff rate for the product ($ln(1 + \tau) = 0$), and thus its magnitude is meaningless. However, the positive coefficient for the interaction term between tariff change and high TFP dummy (0.83) still shows that firms with high productivity has lower tariff absorption elasticity, which is still consistent with the modelprediction for "quality goods".

Table 4 contains the regression results for the smaller sample that only contains the 38 countries with big tariff change: each country has at least one HS6 industry with tariff change higher than 5 percentage points. The regressions in this table are comparable to those in table 3, except that I omit the regressions without any fixed effects (columns 3-4 in table 3) as well as those with only product fixed effect and without GDP and exchange rate changes (columns 5-6 in table 3). The results in this table show the qualitatively same results as those in table 3. First, there is a positive price-productivity schedule (with estimate 0.05), which show that all products as a whole could be described as "quality goods". Second, the absolute magnitude pf tariff absorption is independent of firm productivity, as shown by the insignificance of the estimate for the interaction term between tariff change and firm TFP in column 2. Third, tariff absorption elasticity is higher for low productivity firms, and lower for high productivity firms, as shown by the positive and significant estimates for the interaction term between tariff change and the high TFP dummy in columns 3-6. This is consistent with the model predictions for "quality goods". Finally, the impacts of market size and inital tariff rate on tariff absorption are insignificant, as shown by the estimates for the interaction terms between tariff change and GDP as well as initial tariff rate.

In short, the results presented in this subsection show that all products as a whole could be described as "quality goods"; tariff absorption elasticity is higher for low productivity firms and lower for high productivity firms, which is consistent with the model prediction for "quality goods".

5.2. Cost Goods v.s. Quality Goods

In this subsection I divide all products into two categories, "cost goods" and "quality goods" according to various criteria, and then run the same regressions as in section 5.1 separately for these two groups of products.

As mentioned in section 3, the first criterion that I use to classify products is the price-productivity schedule: a product (HS10) with a negative price-productivity schedule is classified as a "cost good", and a product with a positive price-productivity schedule is classified as a "quality good". Table 5 and table 6 present the regression results for these two groups, respectively, in the same way as table 4.

In table 5 (for "cost goods"), we do have a negative overall price-productivity schedule, as shown in column 1. This is not surprising since each product in this group has a negative price-productivity schedule. Once again, the estimate for the interaction term between tariff change and firm TFP in column 2 is insignificant, indicating that the absolute magnitude of tariff absorption is independent of firm productivity. Column 3 shows that the overall tariff absorption elasticity is 0.88 for "cost goods". However, the estimates in columns 4-6 for the interaction term between tariff change and the high TFP dummy are all insignificant, which shows that the impact of firm productivity on tariff absorption is insignificant for "cost goods". The impacts of market size and initial tariff rate on tariff absorption are not significant, neither.

In table 6 (for "quality goods"), we do have a positive price-productivity schedule, as shown in column 1. The absolute magnitude of tariff absorption is independent of firm productivity, as shown in column 2. Column 3 shows that the overall tariff absorption elasticity is 0.84 for "quality goods". Column 4 shows that the tariff absorption elasticity is higher for low productivity firms (1.53), and lower for high productivity firms (0.09, since $-1.53 + 1.44 = -0.09$), which is consistent with the model prediction for "quality goods". The positive estimates for the interaction term between tariff change and the high TFP dummy in columns 5-6 show the same conclusion. Again the impacts of market size and initial tariff rate on tariff absorption are insignificant.

As also indicated in section 3, the second criterion I use to classify products is the R&D/sales ratio for different industries: I treat goods in industries with a low R&D/sales ratio as "cost goods", and those in industries with a high R&D/sales ratio as "quality goods". Table 7 and table 8 present the regression results for these two groups, respectively.

In table 7 (for "cost goods"), we do not find a significant price-productivity schedule, as shown in column 1. Again the absolute magnitude of tariff absorption is independent of firm productivity, as shown by the insignificance of the estimate for the interaction term between tariff change and TFP in cloumn 2. Column 3 shows that the overall tariff absorption elasticity is 0.85 for "cost goods". The estimates in columns 4-6 for the interaction term between tariff change and the high TFP dummy are all insignificant, which shows that the impact of firm productivity on tariff absorption is insignificant for "cost goods". The impacts of market size and initial tariff rate on tariff absorption are also insignificant.

In table 8 (for "quality goods"), we do have a positive and significant price-productivity schedule, as shown in column 1. Again column 2 shows that the absolute magnitude of tariff absorption is independent of firm productivity. Column 3 shows that the overall tariff absorption elasticity is higher than 1 (1.11) for this group (which again confirms "Metzler Paradox"), since firms not only adjust their regular markups but also adjust their product quality in response to a tariff change. Column 4 shows that the tariff absorption elasticity is higher for low productivity firms (1.82), and lower for high productivity firms (0.37, since $-1.82 + 1.45 = -0.37$), which is consistent with the model prediction for "quality goods". The positive estimates for the interaction term between tariff change and the high TFP dummy in columns 5-6 show the same conclusion. Again the impacts of market size and initial tariff rate on tariff absorption are insignificant.

As also metioned in section 3, the third criterion I use to classify products is the Rauch classification: I treat commodities as "cost goods" and (horizontally) differentiated goods as "quality goods". This is just an approximation, but not accurate. Table 9 and table 10 present the regression results for these two groups, respectively.

In table 9 (for commodities), we do not find a significant price-productivity relationship, as shown in column 1, which indicates that it may not be accurate to treat all commodities as “cost goods”. Once again, the absolute magnitude of tariff absorption is independent of firm productivity, as shown in cloumn 2. Column 3 shows that the overall tariff absorption elasticity is 1.21 for commodities. The estimates in columns 4-6 for the interaction term between tariff change and the high TFP dummy are all negative (though insignificant), which shows that high productivity firms have a higher tariff absorption elasticity than low productivity firms. This is qualitatively consistent with the model prediction for “cost goods”. The impacts of market size and initial tariff rate on tariff absorption are again insignificant.

In table 10 (for differentiated products), we do have a positive and significant price-productivity schedule, as shown in column 1, which shows that differentiated products could be regarded as “quality goods”. Again column 2 shows that the absolute magnitude of tariff absorption is independent of firm productivity. Column 3 shows that the overall tariff absorption elasticity is 0.80 for this group. Column 4 shows that the tariff absorption elasticity is higher for low productivity firms (1.30), and lower for high productivity firms (0.26, since $-1.30 + 1.04 = -0.26$), which is consistent with the model prediction for “quality goods”. The positive estimates for the interaction term between tariff change and the high TFP dummy in columns 5-6 show the same conclusion. Again the impacts of market size and initial tariff rate on tariff absorption are insignificant.

In short, the regression results presented in this subsection show that dividing all products into “cost goods” and “quality goods” in terms of various criteria results in estimates broadly consistent with the model predictions about the impacts of firm productivity on tariff absorption, especially for “quality goods”.

6. Conclusions

This paper explores the incompleteness of tariff pass-through at the firm level, as well as the impacts of firm productivity and product quality differentiation on tariff pass-through. On the theoretical side, I use an extended version of the Melitz and Ottaviano

(2008) model to incorporate product quality, and show that, when exporting firms face a foreign tariff change, they will adjust both their markups and product quality, which leads to a self-adjustment of their tariff-exclusive prices and in turn an incompletene tariff pass-through; The price self-adjustment elasticity (tariff absorption elasticity) and firm productivity are negatively correlated for "quality goods" with high scope for quality differentiation, but positively correlated for "cost goods" with low scope for quality differentiation.

On the empirical side, I use the U.S. transaction-level export data and plant-level manufacturing data, and find evidence for the predictions of the model. In response to a tariff reduction of 10 percentage points, firms on average raise their tariff-exclusive prices by 8.7 percent. All products as a whole could be described as "quality goods", and the price increase is higher for low productivity firms (12.7 percent) and lower for high productivity firms (4.4 precent). Dividing all products into "cost goods" and "quality goods" according to various criteria (price-productivity schedule, R&D/sales ratio, etc.) also results in estimates broadly consistent with model predictions, especially for the group of "quality goods".

The model also has some predictions about the impacts of market size and initial tariff rate on tariff pass-through. However, I did not find empirical evidence for these predictions.

References:

Bagwell, K. and Staiger, W. (2009), "What Do Trade Negotiators Negotiate about? Empirical Evidence from the World Trade Organization", forthcoming *American Economic Review.*

Baldwin, R. and Harrigan, J. (2007), "Zeros, Quality and Space: Trade Theory and trade evidence", *mimeo, University of Virginia.*

Bernard, A. B., Eaton, J., Jensen, J. B., and Kortum, S. (2003), "Plants and Productivity in International Trade", *American Economic Review*, 94(4), 1268-1290.

Bernard, A. B. and Jensen, J. B. (1995), "Exporters, Jobs, and Wages in US Manufacturing: 1976-1987", *Brookings Papers on Economic Activity. Microeconomics*, pp.67-119.

Bernard, A. B. and Jensen, J. B. (1999), "Exceptional Exporter Performance: Cause, Effect, or Both?", *Journal of International Economics*, 47(1), 1-25.

Bernard, A. B., Jensen, J. B., Redding, S., and Schott, P. (2007), "Firms in International Trade", *Journal of Economic Perspectives*, 21(3), 105-130.

Bernard, A. B., Jensen, J. B., and Schott, P. (2006), "Trade Costs, Firms and Productivity", *Journal of Monetary Economics*, 53(5), 917-937.

Bernard, A. B., Jensen, J. B., and Schott, P. (2005), "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trades Goods", *NBER Working Paper*, 11404.

Broda, C., Limao, N., and Weinstein, D. (2008), "Optimal Tariffs and Market Power: The Evidence", *American Economic Review*, 98(5), 2032-65.

Edgeworth, F. Y. (1894), "The Theory of International Values", *Economic Journal*, 4, 35-50.

Feenstra, R. (1989), "Symmetric Pass-through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test, *Journal of International Economics*, 27, 25-45.

Feenstra, R. and Weinstein, D. (2010), "Globalization, Markups, and the U.S. Price Level, *NBER Working Paper*, 15749.

Gervais, A. (2009), "Product Quality and Firm Heterogeneity in International Trade, *Working Paper.*

Kreinin, M. E. (1961),"Effect of Tariff Changes on the Prices and Volumn of Imports", *American Economic Review*, 51(3), 310-24.

Kugler, M. and Verhoogen, E. (2008),"The Quality-complementarity Hypothesis: Theory and Evidence from Colombia", *NBER Working Paper.*

Ludema, R. and Mayda, A. M. (2010),"Do Terms-of-trade Effects Matter for Trade Agreements? Evidence from WTO Countries", *CEPR Discussion Paper, No. 7695.*

Mallick, S. and Marques, H. (2007),"Pass-through of Exchange Rates and Tariffs into Import Prices of India: Currency Depreciation versus Import Liberalization", Working Papers, Center for Globalization Research, No. 3 (September 2007), 287-304.

Mandel, B. (2008),“heterogeneous Firms and Import Quality: Evidence from Transaction-level Prices”, *mimeo, University of California at Davis.*

Melitz, Marc J. (2003), “The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity”, *Econometrica*, Vol. 71, No. 6, 1695-1725.

Melitz, Marc J. and Ottaviano, Gianmarco I. P. (2008), “Market Size, Trade, and Productivity”, *Review of Economic Studies*, 75, 295-316.

Pierce, J. R. and Schott, P. (2009), “A Concordance Between Ten-Digit U.S. Harmonized System Codes and SIC/NAICS Product Classes and Industries”, *NBER Working Paper*, 15548.

Rauch, J. (1999). “ Networks versus Markets in International Trade”. *Journal of International Economics*, 48, 735.

Roberts, M. and Tybout, Y. (1997), “The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs”, *American Economic Review*, pp.545-564.

Table 1. Summary Statistics for Three Samples

	Sample 1			Sample 2			Sample 3		
No. of HS2	94			85			85		
No. of HS6	3,971			2,005			1,979		
No. of HS10	6,301			2,735			2,679		
No. of Firms	21,375			14,404			13,275		
No. of Countries	66			61			38		
TV_{t-1}	1.11×10^{11}			5.28×10^{10}			4.26×10^{10}		
Variables	No. of Obs.	Mean	Std.Dev.	No. of Obs.	Mean	Std.Dev.	No. of Obs.	Mean	Std.Dev.
ΔlnP_{ifct}	172,306	-0.012	1.583	84,902	-0.010	1.474	65,227	-0.009	1.431
$\Delta\tau_{ict}$: all	172,306	-0.007	0.043	84,902	-0.006	0.023	65,227	-0.008	0.026
$\Delta\tau_{ict} < 0$	88,100(0.51)	-0.019	0.031	36,175(0.43)	-0.019	0.028	34,612(0.53)	-0.019	0.028
$\Delta\tau_{ict} = 0$	73,275(0.43)	0	0	45,125(0.53)	0	0	27,047(0.41)	0	0
$\Delta\tau_{ict} > 0$	10,931(0.06)	0.052	0.128	3,602(0.04)	0.035	0.034	3,568(0.06)	0.035	0.035
$lnTFP_{f(t-1)}$	172,306	1.935	0.625	84,902	1.888	0.577	65,227	1.889	0.581

Notes:

(1) Sample 1: 1997-1998, all HS6 industries. (Pre-sample)

(2) Sample 2: 1997-1998, HS6 industries within each there is no tariff variation. (Benchmark Sample)

(3) Sample 3: 1997-1998, countries for which there is at least one HS6 industry with tariff change higher than 5 percentage points. (Sub-sample)

Table 2. **Countries with Big Tariff Change ($|\Delta\tau_{ict}| > 0.05$) in at Least One HS6 Industry**

Country	No. of product-firm-country-year cells with $\|\Delta\tau_{ict}\| > 0.05$	Ranking	Country	No. of product-firm-country-year cells with $\|\Delta\tau_{ict}\| > 0.05$	Ranking
Dominica	457	1	Guatemala	36	21
U.K.	402	2	Sri Lanka	32	22
Canada	279	3	Denmark	29	23
Germany	271	4	Poland	28	24
France	225	5	Brazil	25	25
Nethelands	154	6	China	23	26
Phillipines	154	7	Austria	22	27
Italy	128	8	Venezuela	19	28
El Salvador	111	9	Turkey	10	29
Sweden	111	10	Greece	7	30
Ireland	93	11	Argentina	6	31
Egypt	87	12	Colombia	6	32
Mexico	76	13	Norway	4	33
Belgium	68	14	Hungary	3	34
Costa Rica	62	15	Mauritius	2	35
Panama	61	16	Uruguay	2	36
Honduras	53	17	Ecuador	2	37
Finland	46	18	Madagascar	2	38
Japan	45	19			
Spain	43	20			

Table 3. Tariff Absorption: Benchmark Sample, All Products

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\Delta\tau_{ict}$		-516								
		(33000)								
$lnTFP_{f(t-1)}$	0.06***	1,500***								
	(0.01)	(548)								
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-1700								
		(16000)								
$\Delta ln(1+\tau_{ict})$			-0.09	-0.53	-0.48*	-0.89**	-0.87**	-1.27***	-0.89**	-4.96
			(0.25)	(0.35)	(0.29)	(0.37)	(0.35)	(0.42)	(0.38)	(5.1)
$TFPH_{f(t-1)}$				0.02*		0.02**		0.02**	0.02**	0.02**
				(0.01)		(0.01)		(0.01)	(0.01)	(0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.89*		0.84*		0.83*	0.84*	0.83*
				(0.50)		(0.50)		(0.50)	(0.50)	(0.50)
$\Delta lnXR_{c(t-1)}$									0.03	0.03
									(0.07)	(0.07)
$\Delta lnGDP_{ct}$									-0.0002	-0.01
									(0.05)	(0.05)
$ln(1+\tau_{ic(t-1)})$										0.12
										(0.12)
$lnGDP_{c(t-1)}$										0.0005
										(0.004)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$										4.12
										(3.42)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$										0.14
										(0.19)
Fixed Effects	product ×country	product +country	None	None	product	product	product +country	product +country	product	product
No. of Obs.	84,902	84,902	84,902	84,902	84,902	84,902	84,902	84,902	84,902	84,902
R^2	0.81	0.14	1.6×10^{-6}	6.5×10^{-5}	0.03	0.03	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 4. Tariff Absorption: Countries with Big Tariff Change, All Products

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{ict}$		-2,200				
		(38000)				
$lnTFP_{f(t-1)}$	0.05***	1,800**				
	(0.01)	(695)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-620				
		(973)				
$\Delta ln(1+\tau_{ict})$			-0.65*	-1.08**	-0.75**	-6.96
			(0.35)	(0.43)	(0.38)	(5.3)
$TFPH_{f(t-1)}$				0.03***	0.03**	0.03**
				(0.01)	(0.01)	(0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.90*	0.90*	0.90*
				(0.50)	(0.50)	(0.50)
$\Delta lnXR_{c(t-1)}$					0.04	0.04
					(0.08)	(0.08)
$\Delta lnGDP_{ct}$					-0.07	-0.07
					(0.10)	(0.10)
$ln(1+\tau_{ic(t-1)})$						0.03
						(0.15)
$lnGDP_{c(t-1)}$						0.001
						(0.006)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						3.23
						(3.62)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.22
						(0.19)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	65,227	65,227	65,227	65,227	865,227	65,227
R^2	0.82	0.14	0.04	0.04	0.04	0.04

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 5. Tariff Absorption: Benchmark Sample, Cost Goods —- With a Negative Price-Productivity Schedule

Dependent Variable Regressors	$lnP_{ifc(t-1)}$ (1)	ΔP_{ifct} (2)	ΔlnP_{ifct} (3)	ΔlnP_{ifct} (4)	ΔlnP_{ifct} (5)	ΔlnP_{ifct} (6)
$\Delta\tau_{ict}$		-15,000				
		(40,000)				
$lnTFP_{f(t-1)}$	-0.26***	1,800**				
	(0.02)	(714)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		8,300				
		(20,000)				
$\Delta ln(1+\tau_{ict})$			-0.88*	-1.11*	-0.66	-4.23
			(0.50)	(0.61)	(0.54)	(7.6)
$TFPH_{f(t-1)}$				0.12***	0.12***	0.12***
				(0.02)	(0.02)	(0.02)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.47	0.51	0.49
				(0.43)	(0.73)	(0.73)
$\Delta lnXR_{c(t-1)}$					-0.05	-0.06
					(0.11)	(0.11)
$\Delta lnGDP_{ct}$					0.03	0.01
					(0.08)	(0.08)
$ln(1+\tau_{ic(t-1)})$						0.03
						(0.15)
$lnGDP_{c(t-1)}$						0.19
						(0.18)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						5.91
						(5.15)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.11
						(0.28)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	39,838	39,838	39,838	39,838	39,838	39,838
R^2	0.78	0.25	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 6. Tariff Absorption: Benchmark Sample, Quality Goods —- With a Positive Price-Productivity Schedule

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \tau_{ict}$		30,000				
		(55,000)				
$lnTFP_{f(t-1)}$	0.43***	1,100**				
	(0.02)	(839)				
$\Delta \tau_{ict} \times lnTFP_{f(t-1)}$		-19,000				
		(26,000)				
$\Delta ln(1+\tau_{ict})$			-0.84*	-1.53***	-1.26**	-6.35
			(0.49)	(0.60)	(0.52)	(6.89)
$TFPH_{f(t-1)}$				-0.06***	-0.06***	-0.06***
				(0.01)	(0.01)	(0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				1.44**	1.41**	1.40**
				(0.70)	(0.70)	(0.70)
$\Delta lnXR_{c(t-1)}$					0.13	0.12
					(0.10)	(0.10)
$\Delta lnGDP_{ct}$					-0.03	-0.03
					(0.07)	(0.07)
$ln(1+\tau_{ic(t-1)})$						0.05
						(0.15)
$lnGDP_{c(t-1)}$						0.002
						(0.006)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						2.65
						(4.59)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.18
						(0.25)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	45,064	45,064	45,064	45,064	45,064	45,064
R^2	0.83	0.04	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 7. Tariff Absorption: Benchmark Sample, Cost Goods
—- With a Low R&D/Sales Ratio

Dependent Variable Regressors	$lnP_{ifc(t-1)}$ (1)	ΔP_{ifct} (2)	ΔlnP_{ifct} (3)	ΔlnP_{ifct} (4)	ΔlnP_{ifct} (5)	ΔlnP_{ifct} (6)
$\Delta\tau_{ict}$		-2,000				
		(3,900)				
$lnTFP_{f(t-1)}$	0.18	93				
	(0.19)	(74)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		177				
		(2,200)				
$\Delta ln(1+\tau_{ict})$			-0.85*	-1.10**	-0.73	-0.67
			(0.45)	(0.53)	(0.45)	(6.65)
$TFPH_{f(t-1)}$				-0.003	-0.003	-0.003
				(0.013)	(0.013)	(0.013)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.53	0.55	0.54
				(0.61)	(0.61)	(0.61)
$\Delta lnXR_{c(t-1)}$					0.06	0.06
					(0.10)	(0.10)
$\Delta lnGDP_{ct}$					0.02	0.01
					(0.07)	(0.07)
$ln(1+\tau_{ic(t-1)})$						0.09
						(0.14)
$lnGDP_{c(t-1)}$						-0.003
						(0.006)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						3.06
						(4.44)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						-0.03
						(0.25)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	44,167	44,167	44,167	44,167	44,167	44,167
R^2	0.77	0.04	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 8. Tariff Absorption: Benchmark Sample, Quality Goods
—- With a High R&D/Sales Ratio

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{ict}$		-7,500				
		(80,000)				
$lnTFP_{f(t-1)}$	0.17***	-2,400**				
	(0.02)	(1,000)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		4,000				
		(33,000)				
$\Delta ln(1+\tau_{ict})$			-1.11*	-1.82**	-1.23*	-11.20
			(0.62)	(0.74)	(0.65)	(9.10)
$TFPH_{f(t-1)}$				0.05***	0.05***	0.05***
				(0.02)	(0.02)	(0.02)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				1.45*	1.43*	1.42*
				(0.84)	(0.84)	(0.84)
$\Delta lnXR_{c(t-1)}$					0.02	0.004
					(0.10)	(0.103)
$\Delta lnGDP_{ct}$					-0.02	-0.03
					(0.08)	(0.08)
$ln(1+\tau_{ic(t-1)})$						0.162
						(0.21)
$lnGDP_{c(t-1)}$						0.004
						(0.007)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						4.47
						(5.50)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.36
						(0.33)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	40,735	40,735	40,735	40,735	40,735	40,735
R^2	0.78	0.14	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 9. Tariff Absorption: Benchmark Sample, Commodities
—- With Low Scope for Horizontal Differentiation

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{ict}$		231				
		(7,700)				
$lnTFP_{f(t-1)}$	0.23	-37.4				
	(0.15)	(207)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		47.5				
		(6,100)				
$\Delta ln(1+\tau_{ict})$			-1.21**	-0.73	-0.67	22.4*
			(0.60)	(0.72)	(0.65)	(13.6)
$TFPH_{f(t-1)}$				0.007	0.008	0.008
				(0.02)	(0.02)	(0.02)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				-1.14	-1.10	-1.18
				(0.92)	(0.91)	(0.92)
$\Delta lnXR_{c(t-1)}$					0.19	0.17
					(0.17)	(0.18)
$\Delta lnGDP_{ct}$					0.16	0.15
					(0.10)	(0.10)
$ln(1+\tau_{ic(t-1)})$						0.11
						(0.18)
$lnGDP_{c(t-1)}$						-0.01
						(0.01)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						-3.41
						(8.16)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						-0.86*
						(0.49)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	6,171	6,171	6,171	6,171	6,171	6,171
R^2	0.86	0.07	0.08	0.08	0.07	0.07

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 10. Tariff Absorption: Benchmark Sample, Differentiated Products —- With High Scope for Horizontal Differentiation

Dependent Variable	$lnP_{ifc(t-1)}$	ΔP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}	ΔlnP_{ifct}
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{ict}$		-1,300				
		(40,000)				
$lnTFP_{f(t-1)}$	0.05***	-1,600				
	(0.01)	(592)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-1,300				
		(18,000)				
$\Delta ln(1+\tau_{ict})$			-0.80**	-1.30***	-0.93**	-6.73
			(0.38)	(0.46)	(0.41)	(5.37)
$TFPH_{f(t-1)}$				0.02**	0.2**	0.02**
				(0.01)	(0.01)	(0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				1.04*	1.05*	1.04*
				(0.54)	(0.54)	(0.54*)
$\Delta lnXR_{c(t-1)}$					0.03	0.02
					(0.07)	(0.08)
$\Delta lnGDP_{ct}$					-0.02	-0.03
					(0.06)	(0.06)
$ln(1+\tau_{ic(t-1)})$						0.13
						(0.13)
$lnGDP_{c(t-1)}$						0.001
						(0.005)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						4.37
						(3.62)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.20
						(0.20)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	78,731	78,731	78,731	78,731	78,731	78,731
R^2	0.80	0.14	0.03	0.03	0.03	0.03

Notes: Standard errors are reported in parentheses. *, **, and *** denote the 10, 5, and 1 percent of significance levels.