ESSAYS ON TARIFF PASS-THROUGH AND SPILLOVER EFFECT

A Dissertation
submitted to the Faculty of the
Graduate School of Arts and Sciences
of Georgetown University
in partial fulfillment of the requirements for the
degree of
Doctor of Philosophy
in Economics

By

Zhi Yu, Ph.D.

Washington, DC
May 25, 2011

ESSAYS ON TARIFF PASS-THROUGH AND SPILLOVER EFFECT

Zhi Yu, Ph.D.

Thesis Advisor: Rodney Ludema, Ph.D.

ABSTRACT

Essay 1 is the first attempt to explore tariff pass-through at the firm level, and to investigate how it depends on firm heterogeneity in productivity and product differentiation in quality. Using an extended version of the Melitz and Ottaviano (2008) model, the essay shows that exporting firms absorb tariff changes by adjusting both their markups and product quality, which leads to an incomplete tariff pass-through. Moreover, the absolute value of tariff absorption elasticity negatively depends on firm productivity for products with high scope for quality differentiation, but positively depends on firm productivity for products with low scope for quality differentiation. Essay 2 studies how market structure impacts tariff pass-through. The essay explores this with a model in which both export firms and import firms have some market power. It shows that tariff pass-through is negatively related to the market power of export firms, but is ambiguously related to the market power of import firms. This is due to the impact of their market power on the markup distribution between export firms and import firms. Essay 3 studies how tariff changes of a country impact trade prices between its trade partners. The essay uses a simple model to show that, when a foreign country reduces its tariffs (either MFN or non-MFN tariffs), domestic exporting firms raise their prices toward third countries, which is referred to as "tariff spillover effect". The existence of the effect depends on the assumption of increasing marginal cost. The essays use the U.S. transaction-level export or import data and find empirical evidence for the predictions of the models.

Table Of Contents

Essay 1. Tariff Pass-through, Firm Heterogeneity and Product Quality[§]

Rodney Ludema[†]
Georgetown University

Zhi Yu[‡]
Georgetown University

July 2011

Abstract: Previous studies on tariff pass-through have been conducted at the industry level. This paper is the first attempt to explore tariff pass-through at the firm level, and to investigate how it depends on firm heterogeneity in productivity and product differentiation in quality. Using an extended version of the Melitz and Ottaviano (2008) model, we show that exporting firms absorb tariff changes by adjusting both their markups and product quality, which leads to an incomplete tariff pass-through. Moreover, the absolute value of tariff absorption elasticity (the percentage change in the tariff-exclusive export price in response to a one percent change in the gross tariff rate) negatively depends on firm productivity for products with high scope for quality differentiation, but positively depends on firm productivity for products with low scope for quality differentiation. Using the U.S. transaction-level export data and plant-level manufacturing data, we find evidence for these predictions. The firm-level tariff absorption elasticity is −0.87 on average. Pooled regressions reveal that the tariff absorption elasticity is higher (in terms of absolute value) for low productivity firms (−1.27) and lower for high productivity firms (−0.44). Estimation done separately on quality differentiated goods and quality homogeneous goods finds that the inverse relationship between tariff absorption elasticity and firm productivity is more pronounced for quality differentiated goods and non-existent for quality homogeneous goods, which is consistent with the model.

Key Words: Tariff Pass-through, Firm Heterogeneity, Product Quality, Markups
JEL Numbers: F1, D2, L1

[§] The authors thank J. Bradford Jensen, Anna Maria Mayda, Antoine Gervais, Tom Holmes, William Kerr, Kala Krishna, Ben Mandel, Tom Prusa, Andres Rodriguez-clare, Daniel Reyes, French Scott, Justin Pierce, Cheryl Grim, and participants at Georgetown International Economics Seminar, the Midwest Trade Meetings, the Southern Economic Association Conference, the Census Bureau RDC Research Conference, and the Eastern Economic Association Conference for helpful comments and discussions. Zhi Yu also thanks Lynn Riggs of the Census Bureau for technical support and Jim Davis of the NBER for timely disclosure of the data analysis. Support for this research at the Census Bureau RDC from NSF (ITR-0427889) is also gratefully acknowledged. The research in this paper was conducted while Zhi Yu was a Special Sworn Status researcher at the U.S. Census Bureau, Center for Economic Studies. Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.

[†] Georgetown University, Department of Economics, 37th and O Streets, Washington, DC 20057, U.S.A. E-mail: ludemar@georgetown.edu.

[‡] Georgetown University, Department of Economics, 37th and O Streets, Washington, DC 20057, U.S.A. E-mail: zy24@georgetown.edu.

1. Introduction

This paper is the first attempt to explore tariff pass-through at the firm level, and to investigate how it depends on firm heterogeneity in productivity and product differentiation in quality. Using an extended version of the Melitz and Ottaviano (2008) model, we show that exporting firms absorb tariff changes by adjusting both their markups and product quality, which leads to an incomplete tariff pass-through. Moreover, tariff absorption elasticity (the percentage change in the tariff-exclusive export price in response to a one percent change in the gross tariff rate) negatively depends on firm productivity for products with high scope for quality differentiation, but positively depends on firm productivity for products with low scope for quality differentiation. Using the U.S. transaction-level export data and plant-level manufacturing data, we find evidence for these predictions: The firm-level tariff pass-through is indeed incomplete, and tariff absorption does depend on firm productivity and product quality as the model predicts, especially for quality differentiated goods.

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 large country raises its tariff rate on a product, foreign countries that sell in its market may absorb part of the tariff increase by lowering their tariff-exclusive 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[2]. This terms-of-trade effect is the basis for the optimal tariff argument and a driving force for international trade agreements, as shown in Edgeworth (1894), Broda, Limão and Weinstein (2008), Bagwell and Staiger (2009), and Ludema

[1] For this reason we also refer to incomplete tariff pass-through as "tariff absorption" hereafter. Graphically, tariff-absorption is represented by the downward movement along the upward-slopping foreign export supply curve of the home country.

[2] Similarly, tariff reduction of a large country leads to increases of the tariff-exclusive prices of foreign countries that sell in its market, and thus has an opposite terms-of-trade effect.

and Mayda (2010).[3]

There have been several empirical studies on the incompleteness of tariff pass-through. Feenstra (1989) finds that around 40 percent of the U.S. tariff increase in 1980s against the imports of Japanese automobiles was passed on as lower prices to Japanese automobile exports to the U.S. Kreinin (1961) finds that more than two-thirds of U.S. tariff reductions in Geneva 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 have been done at the industry level. That is, they study how the average price of all firms in an industry responds to a tariff change[4]. In these studies, it was not clear 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 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.[5] Thus firm-level studies are needed to investigate this.

For this purpose, we turn to the second literature relevant to this paper — heterogeneous firm models of international trade, since these models focus on the intra-industry reallocation between firms. Heterogeneous firm models were spurred by empirical studies, beginning with Bernard and Jensen (1995)[6], which use plant or firm-level data to document that exporting firms are on average larger and more productive than non-exporting firms. These models are characterized by firm heterogeneity in productivity, and focus

[3]The optimal argument says that, 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. Broda, Limão and Weinstein (2008) examine this with the tariff schedules of non-WTO countries; Bagwell and Staiger (2009) consider this with changes in the tariff schedules of recent WTO accession countries; Ludema and Mayda (2010) explore this with MFN tariffs set by existing WTO members.

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

[5]In another paper, Feenstra and Weinstein (2010) estimate the magnitude of markup reduction and welfare gain 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.

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

on the intra-industry reallocation between firms caused by changes in trade environment. The representative models include 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 utility, with the latter implying constant markups. With constant marginal cost and markups, firms do not have any room for price adjustment. Thus the firm-level tariff pass-through is complete, and 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 that, after tariff increase, the surviving exporting firms, which are more productive than the exiting firms, should have lower-than-average prices, so that the average industry price after the tariff increase is lower than before. However, this contradicts the prediction of 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 more productive firms could have higher-than-average prices since they produce high quality differentiated goods. 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 very convincing in explaining the incompleteness of tariff pass-through.

Given this consideration, we 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, the firm-level tariff pass-through could be incomplete, since firms could adjust their markups and hence their exporting prices in response to a tariff change, even if they have constant marginal cost. 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 firm-level tariff pass-through.

Our model is similar to Antoniades (2008). The difference is that the quality-upgrading cost in his model only contains a quantity-invariant R&D cost, but in our model we add another type of quality-upgrading cost, the quantity-dependent component-upgrading cost. This extension makes it easier to justify that a firm chooses different quality levels for different markets, which is crucial to guarantee a closed form solution to the model. In our model, exporting firms absorb the tariff change not only by adjusting their markups due to the linear demand structure, but also by adjusting the quality of their products. Both these two adjustments lead to an incomplete tariff pass-through. Moreover, high productivity firms have high absolute magnitude of quality adjustment and tariff absorption. For products with high scope for quality differentiation, the relative tariff absorption, i.e., tariff absorption elasticity, is lower for high productivity firms, since their initial prices are higher. In contrast, for products with low scope for quality differentiation, the tariff absorption elasticity is higher for high productivity firms, since their initial prices are low. In sum, the model predicts that tariff pass-through depends on both firm heterogeneity in productivity and product differentiation in quality.

In order to empirically test these predictions, we need to use firm-level data on trade and productivity, as well as product level data on quality scope. From the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD) we construct the U.S. firm-level export price changes over time for each exported product to each destination country. From the World Integrated Trade Solution (WITS) we get the changes of tariff rates of other countries against U.S. exports of different products. We also use the U.S. Census of Manufacturing (CMF) data to construct the firm-level productivity, and use the R&D/sales ratio data from the National Science Foundation or Rauch classification to derive the quality scope of different industries/products. Then we link the tariff data, the firm productivity data, and the product quality scope data to the export price data. We use the combined data in 1997-1998 (part of the applied period of Uruguay Round), during which there are a wide range of large tariff changes and relatively accurate data for firm productivity and product quality scope, to test model predictions. We conduct the empirical analysis for the full sample, quality homogeneous goods, and quality differentiated goods, respectively. For each sample, we test the price-productivity schedule, and check whether the firm-level tariff pass-through is incomplete as well as how the absolute and relative tariff absorption depends on firm productivity.

We find evidence supporting the predictions of the model. First, we find that firm-level tariff pass-through is indeed incomplete: The firm-level tariff absorption elasticity is -0.87 on average. Second, pooled regressions reveal that products in the sample on average fit the definition of quality differentiated goods, and the tariff absorption elasticity is higher (in terms of its absolute value) for low productivity firms (-1.27) and lower for high productivity firms (-0.44), as the model predicts for products with high scope for quality differentiation. The overall tariff absorption elasticity and that for low productivity firms are very high (in terms of the absolute value), since firms change not only their markups but also their product quality in response to tariff changes. Third, estimation done separately on quality differentiated goods and quality homogeneous goods finds that the inverse relationship between tariff absorption elasticity and productivity is more pronounced for quality differentiated goods and non-existent for quality homogeneous goods, which is consistent with the model.

To our knowledge, this is the first paper that (1) finds empirical evidence for incomplete tariff pass-through at the firm level, and (2) investigates, both theoretically and empirically, how tariff pass-through depends on firm productivity and product quality. Both of these two are contributions of the paper to the tariff pass-through literature. The second one is also a 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 describes the data used. Section 4 contains the empirical strategies and results. Conclusions are included in section 5.

2. The Model

2.1. Consumers and Demand

As mentioned in section 1, our 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 varieties 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 incurs 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 right 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. 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 definition of "R&D cost" for quality upgrading. The second term, $b q_i z_i$, depends on both the quantity and the quality of the output, which captures the definition of "component-upgrading cost" associated with quality upgrading. A firm could choose a component with one quality level for the home market but another component with another quality level for the foreign market.

There are three things worth pointing out. First, both the "processing cost" and the "R&D cost" exist in Antoniades (2008), but the "component-upgrading cost" is what we add to his model. The purpose of this extension is to justify that a firm can choose different product quality levels for different markets, which is crucial to ensure a closed form solution to the model, as will be shown below. Second, c_i is a firm-specific constant which indexes the marginal processing cost; parameters b and θ are product-specific constants which index the "toughness" of quality upgrading for a product, but they are common across all firms producing different varieties of the same product. Third, c_i is the marginal "processing" cost of the firm, and the overall marginal cost of the firm is $MC_i = c_i + b z_i$, where z_i is a function of c_i (as will be shown shortly). $1/c_i$ indexes the processing productivity of the firm, and $1/MC_i$ indexes the overall productivity of the firm.

The timing of firms' decisions is as follows. First, firms learn about product-specific, quality-upgrading costs b and θ, the distribution of firm processing cost $G(c)$, and the fixed entry cost f_E, all of which are common knowledge, and they decide whether to enter the industry or not. Second, after they enter the industry by making the irreversible investment f_E, they learn about their individual processing cost c_i, and decide on the quality and price for the product that they will produce.

Consider a firm in the Home country h with 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. As mentioned above, the validity of the second assumption is based on the "component-upgrading cost" that we add to Antoniades (2008). 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:

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

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:

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

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; $\lambda^{hh} = \frac{(\gamma-b)L^h}{4\gamma\theta-(\gamma-b)^2L^h}$ and $\lambda^{hf} = \frac{(\gamma-\tau^f b)L^f}{4\gamma\theta\tau^f-(\gamma-\tau^f b)^2L^f}$. We can show that $c^{hf} = c^{ff}/\tau^f$. Assume that $\gamma - b > 0$,

$\gamma - \tau^f b > 0$, $4\gamma\theta - (\gamma - b)^2 L^h > 0$ and $4\gamma\theta\tau^f - (\gamma - \tau^f b)^2 L^f > 0$ to ensure z^{hh} and z^{hf} to be positive.

We can also show that the level of quality upgrading that the firm chooses (z^{hh} or z^{hf}) is increasing in (i) the processing productivity of the firm ($1/c$), (ii) the market size (L^h or L^f), and (iii) the degree of product horizontal differentiation (γ), but it is decreasing in (i) the toughness for quality upgrading (θ and b), and (ii) the foreign tariff rate (τ^f). The intuition for these conclusions is straightforward and thus is omitted here.

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:

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

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

It is very helpful to have a careful examination for the 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., an adjustment of their tariff-exclusive prices.

Here we focus on the tariff-exclusive price:

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

where $B = \frac{2\gamma\theta\tau^f - \gamma(\gamma - \tau^f b)L^f}{4\gamma\theta\tau^f - (\gamma - \tau^f b)^2 L^f}$, and $1 - B = \frac{2\gamma\theta\tau^f + \tau^f b(\gamma - \tau^f b)L^f}{4\gamma\theta\tau^f - (\gamma - \tau^f b)^2 L^f} > 0$.

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 quantity processing; the second term, $\frac{(\gamma + \tau^f b)}{2}\frac{z^{hf}}{\tau^f}$, is derived from the quality upgrading. We refer to these two terms as the quantity component p_q^* and the quality component p_z^*, respectively — as indicated by the third equality (equivalence).

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

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

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

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

We refer to this as the "quality effect": the higher is firm processing productivity, the higher is the product quality level that the firm will choose (as mentioned in section 2.2), and thus the higher is the quality-upgrading cost and the unit price.

The fifth (the last) equality describes the relationship between the overall price and firm processing productivity. From this equality we can get

$$\frac{\partial p^*}{\partial(\frac{1}{c})} < 0 \qquad \text{if} \qquad B > 0, i.e., \left(\frac{2\theta}{L^f} + b\right)\tau^f > \gamma, \tag{11}$$

$$\frac{\partial p^*}{\partial(\frac{1}{c})} > 0 \qquad \text{if} \qquad B < 0, i.e., \left(\frac{2\theta}{L^f} + b\right)\tau^f < \gamma. \tag{12}$$

The intuition is as follows. The condition $\left(\frac{2\theta}{L^f} + b\right)\tau^f > \gamma$ implies that (1) the quality-upgrading toughness for the product, θ and b, are relatively high, (2) the foreign tariff rate, τ^f, is relatively high, (3) the market size, L^f, is relatively small, and (4) the product horizontal differentiation γ is relatively low. All these imply that the quality level chosen by all firms (producing different varieties of the same product) is relatively low (as mentioned in section 2.2), and the product has low scope for quality differentiation. As the result, the "processing effect" dominates the "quality effect", and hence the overall price is negatively related to firm processing productivity — We refer to this type of products as "quality homogeneous goods". In contrast, the condition $\left(\frac{2\theta}{L^f} + b\right)\tau^f < \gamma$ implies that the opposite is true: the product has high scope for quality differentiation, and the overall price is positively related to firm processing productivity — We refer to this type of products as "quality differentiated goods".

An interesting observation here is that the horizontal differentiation of a product γ is related to the vertical differentiation or quality scope of the product. A product with low horizontal differentiation γ is also likely to have low vertical differentiation or quality scope, and thus is likely to be a quality homogeneous good. A product with high horizontal differentiation γ is also likely to have high vertical differentiation or quality scope, and thus is likely to be a quality differentiated good.

2.4. Tariff Absorption, Firm Productivity and Product Quality

Now we shall turn to explore how a tariff change impacts the tariff-exclusive price

p^*. From (8) we can derive that the absolute magnitude of this impact is

$$\begin{aligned}\frac{\partial p^*}{\partial \tau^f} =& -\frac{\partial B}{\partial \tau^f}(c^{hf} - c) + (1 - B)\frac{\partial c^{hf}}{\partial \tau^f} \\ <& 0.\end{aligned} \tag{13}$$

The last inequality holds since we can show that $\frac{\partial B}{\partial \tau^f} > 0$, $1 - B > 0$, and $\frac{\partial c^{hf}}{\partial \tau^f} < 0$, and $c^{hf} - c > 0$ by definition of cost bound. The relative magnitude of the impact is

$$\begin{aligned}\Theta^* \equiv& \frac{\partial p^*}{\partial \tau^f}\frac{\tau^f}{p^*} \\ =& \left[-\frac{\partial B}{\partial \tau^f}(c^{hf} - c) + (1 - B)\frac{\partial c^{hf}}{\partial \tau^f}\right]\frac{\tau^f}{(1 - B)c^{hf} + Bc} \\ <& 0.\end{aligned} \tag{14}$$

The negative signs of the absolute and relative price changes in response to a tariff change imply the incompleteness of tariff pass-through, i.e., "tariff absorption": the tariff-exclusive export price increases in response to a tariff reduction[7]. Θ^* is the tariff absorption elasticity: the percentage increase in the tariff-exclusive export price in response to a one percent decrease in the gross tariff rate.

There are three things worth pointing out. First, we can verify 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 processing 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

[7]Note that here, and hereafter, we interpret "tariff absorption" in terms of the increase of the tariff-exclusive price in response to a tariff reduction, instead of the decrease of the tariff-exclusive price in response to a tariff increase (as in section 1). This is mainly because that most tariff changes in the real world are tariff reductions instead of tariff increases, as will be indicated in section 4.

[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-upgrading 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-upgrading cost. (2) However, the sign of the markup change associated with quality-upgrading, $\frac{\partial u_z}{\partial \tau^f}$, is ambiguous, where $u_z = p_z^* - c_z$.

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, we can show that the absolute magnitude of tariff absorption, in terms of its absolute value, positively depends on firm processing productivity, i.e.,

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

We can also verify that, the absolute increase of the quantity component of the tariff-exclusive price in response to a tariff reduction is independent of firm processing productivity, that is, $\frac{\partial|\partial p_q^*/\partial\tau^f|}{\partial(\frac{1}{c})} = 0$.[9] However, the absolute increase of the quality component of the tariff-exclusive price in response to a tariff reduction is positively related to firm processing productivity, that is, $\frac{\partial|\partial p_z^*/\partial\tau^f|}{\partial(\frac{1}{c})} > 0$; this is because that firms with high processing productivity will upgrade their product quality more than firms with low processing productivity, i.e., $\frac{\partial|\partial z^{hf}/\partial\tau^f|}{\partial(\frac{1}{c})} > 0$, since their ability for quality upgrading is high.

Third, the relative magnitude of tariff absorption, i.e., the tariff absorption elasticity, depends on firm processing productivity in the following way:

$$\frac{\partial|\Theta^*|}{\partial(\frac{1}{c})} > 0 \qquad \text{if} \qquad B > 0, i.e., \left(\frac{2\theta}{L^f} + b\right)\tau^f > \gamma, \tag{16}$$

$$\frac{\partial|\Theta^*|}{\partial(\frac{1}{c})} \sim 0 \qquad \text{if} \qquad B < 0, i.e., \left(\frac{2\theta}{L^f} + b\right)\tau^f < \gamma, \tag{17}$$

$$\frac{\partial|\Theta^*|}{\partial(\frac{1}{c})} < 0 \qquad \text{if} \qquad B \ll 0, i.e., \left(\frac{2\theta}{L^f} + b\right)\tau^f \ll \gamma, \tag{18}$$

where the notation "$\sim$" in (17) denotes "greater than, equal to, or less than", and "$\ll$" in (18) denotes "far less than". Notice that the condition $\frac{2\theta}{L^f} + b > \gamma$ implies that the

[9]This is due to the following reason. From equation (8) we can see that p_q^* consists of two additive components (which is determined by the linear demand function): the first component (c^{hf}) depends on foreign tariff rate but not firm processing productivity, and the second component (c) depends on firm processing productivity but not foreign tariff rate. When foreign tariff rate changes, only the first component changes, which does not depend on firm processing productivity.

product is a quality homogeneous good, $\frac{2\theta}{L^f} + b < \gamma$ implies that the product is a quality differentiated good, and $\frac{2\theta}{L^f} + b \ll \gamma$ implies that the product is a quality differentiated good and the scope for quality differentiation is very high.

These results could be explained by the impacts of firm processing productivity ($1/c$) on both the numeraire and the denominator of the tariff absorption elasticity ($\Theta^* \equiv \frac{\partial p^*}{\partial \tau^f} \frac{\tau^f}{p^*}$). As for the numeraire ($\partial p^*/\partial \tau^f$), we have seen that the absolute magnitude of tariff absorption, in terms of its absolute value, positively depends on firm processing productivity, as indicated in (15). As for the denominator (p^*, the initial export price), its relationship with firm processing productivity is determined by product quality scope. For quality homogenous goods, the initial export price is negatively related to firm processing productivity, as indicated in (11). Thus the tariff absorption elasticity, in terms of its absolute value, is positively related to firm processing productivity ($1/c$), as indicated in (16). In contrast, for a quality differentiated good, the initial export price is positively related to firm processing productivity, as indicated in (12). Thus the relationship between the tariff absorption elasticity, in terms of its absolute value, and firm processing productivity is ambiguous (as indicated in (17)), depending on whether the numeraire or the denominator effect is dominant. If the product quality scope is sufficiently high, then the denominator effect dominates the numeraire effect, and thus the tariff absorption elasticity (in terms of its absolute value) is negatively related to firm processing productivity, as indicated in (18).[10]

These results could also be explained in another way. We can verify that, the relative increase of the quantity component of the tariff-exclusive price in response to a tariff reduction is positively related to firm processing productivity, that is, $\frac{\partial |\Theta_{p_q^*}|}{\partial (\frac{1}{c})} > 0$, where $\Theta_{p_q^*} \equiv \frac{\partial p_q^*}{\partial \tau^f} \frac{\tau^f}{p_q^*} < 0$. [11] We can also refer to this as "processing effect", as our interpretation for (9). However, the relative increase of the quality component of the tariff-exclusive price in response to a tariff reduction is negatively related to firm processing productivity, that is, $\frac{\partial |\Theta_{p_z^*}|}{\partial (\frac{1}{c})} < 0$, where $\Theta_{p_z^*} \equiv \frac{\partial p_z^*}{\partial \tau^f} \frac{\tau^f}{p_z^*} < 0$; this is because that firms with high processing

[10] We can also show with numerical examples that there indeed exist model parameters that make this case possible.

[11] This is due to two facts: $\frac{\partial |\partial p_q^*/\partial \tau^f|}{\partial (\frac{1}{c})} = 0$ and $\frac{\partial p_q^*}{\partial (\frac{1}{c})} < 0$.

productivity will upgrade their product quality by a less percentage, i.e., $\frac{\partial|\Theta_{z^{hf}}|}{\partial(\frac{1}{c})} < 0$, where $\Theta_{z^{hf}} \equiv \frac{\partial z^{hf}}{\partial \tau^f}\frac{\tau^f}{z^{hf}} < 0$, since their initial quality level is already high and thus the quality-upgrading cost is also high. We can also refer to this as "quality effect", as our interpretation for (10). For quality homogenous goods, the "processing effect" dominates the "quality effect", and thus we see a positive relationship between the overall tariff absorption elasticity ($|\Theta^*|$) and firm processing productivity ($1/c$), as indicated in (16). For quality differentiated goods with high scope for quality differentiation, the "processing effect" is dominated by the "quality effect", and thus we see a negative relationship between the overall tariff absorption elasticity ($|\Theta^*|$) and firm processing productivity ($1/c$), as indicated in (18). For quality differentiated goods with medium scope for quality differentiation, it is not quite clear which effect is dominant, and thus we end up with an ambiguous relationship between the overall tariff absorption elasticity ($|\Theta^*|$) and firm processing productivity ($1/c$), as indicated in (17).

Table 1 summarizes the model predictions for comparative statics regarding (i) price and productivity, (ii) tariff absorption, (iii) absolute tariff absorption and productivity, as well as (iv) relative tariff absorption and productivity.

Notice that in (11)-(12) and (15)-(18), we focus on the relationship between export price or tariff absorption and firm "processing" productivity ($1/c$). We can show that, for exported goods, the overall marginal cost is $MC = \partial TC^{hf}/\partial q^{hf} = c + bz^{hf} = c + b\lambda(c^{hf} - c) = b\lambda c^{hf} + (1 - b\lambda)c$. Under the condition $1 - b\lambda > 0$ (which we assume is true), the overall marginal cost MC and the marginal "processing" cost (c) are positively correlated. Then all the relationships mentioned above ((11)-(12) and (15)-(18)) could be re-written and re-interpreted in terms of firm overall productivity ($1/MC$).

3. Data

Now we turn to the empirical side. We use the U.S. export data to test the model predictions on how tariff absorption depends on firm heterogeneity in productivity and product differentiation in quality. Four types of data are needed for empirical analysis: trade data, tariff data, firm productivity data, and product quality scope data.

3.1. Trade Data

The trade data are used to compute firm-level export prices. The data that we use is the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which was assembled by Bernard, Jensen and Schott (2008). The data link all individual U.S. import and export transactions to the respective U.S. importing and exporting firms. The dataset comes from two sources: the first one is the foreign trade data (FTD) assembled by the U.S. Census Bureau and U.S. customs, which contains all U.S. international trade transactions between 1992 and 2005 inclusive; the second is the Longitudinal Business Database (LBD) of the U.S. Census Bureau, which records annual employment and survival information for most U.S. establishments. We use the export data in the LFTTD database. For each export transaction, the database records its product category (at HS10 level), quantity, (tariff-exclusive) value, exporting firm, destination country, year and month in which the transaction occurs, etc.

Before constructing export prices we clean the data in the following way. (1) We drop transactions 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, we remove the transactions (around 5 percent of the total) with extraordinary computed prices which are 20 times higher or lower than the average price of all transactions in the same product-firm-country-year cell. (3) We also remove related party transactions[12] (around 30 percent of the total), since the price behavior for related party transactions is quite different from normal arm's length transactions. For the rest of transactions, we construct firm-level prices (unit values) as $P^*_{ifct} = V_{ifct}/Q_{ifct}$, 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. The constructed export prices are tariff-exclusive since export values are tariff-exclusive. Among all product-firm-country-year cells for which we constructed export prices, we keep those surviving in two consecutive years, and computer changes of absolute prices $\Delta P^*_{ifct} = P^*_{ifct} - P^*_{ifc(t-1)}$

[12]Related-party transactions refer to trade between U.S. companies and their foreign subsidiaries and trade between U.S. subsidiaries of foreign companies and their affiliates abroad.

and changes of log prices $\Delta lnP^*_{ifct} = lnP^*_{ifct} - lnP^*_{ifc(t-1)}$.

3.2. Tariff Data

The tariff data contain the tariff rates of other countries against U.S. exports of different products. The data were collected by the World Integrated Trade Solution (WITS) 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 HS8 or HS10 products within a same HS6 category. For each HS6 category, the data include the maximum, minimum, and mean tariff rates of all HS8 or HS10 products within the category. We only include HS6 categories within which there is no tariff variation (that is, the maximum, minimum and mean tariff rates are all identical), since it is only for these HS6 categories that we can calculate accurate tariff change over time for products at HS10 level[13], $\Delta\tau_{ict}$. These tariff changes are then merged to U.S. export price changes of corresponding products to corresponding destination countries.

3.3. Firm Productivity Data

Firm productivity is constructed from the U.S. Census of Manufactures (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). From this data we 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; Q, K, L, E and M represent plant-level output (value of shipment), capital stocks, labor hours, and energy and materials inputs;

[13]For a HS6 industry within which there is tariff variation across HS8 or HS10 products, we can only calculate the change of average tariff rate for the HS6 industry, but not the accurate tariff change for each HS8 or HS10 product.

and the ϕ's are the factor elasticities for the corresponding 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[14], and is then merged to the U.S. export price changes of corresponding firms.

3.4. Product Quality Scope Data

The model predicts that the relationship between tariff absorption and firm productivity depends on product scope for quality differentiation. Thus we also need data to identify product quality scope. Since product quality is not directly observed, it is hard to find a very good criterion to identify the quality scope of a product. A potential criterion is the price-productivity schedule for each individual product. According to the model, if a product has a negative price-productivity schedule, then it could be classified as a quality homogeneous good; if it has a positive price-productivity schedule, then it could be classified as a quality differentiated good. We can even possibly use the slope of price-productivity schedule to measure the magnitude of the quality scope of a product. However, this method may cause an endogeneity problem: if 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 variables in the first stage are related to those in the second stage, and thus there may exist an endogeneity problem between these two stages.

Given this consideration, we turn to exogenous criteria for product quality scope. The first one that we are going to use is the Rauch classification. Rauch (1999) classifies products into commodities and differentiated goods: goods traded on organized exchanges or with reference prices are classified as commodities, and others are classified as differentiated goods. Intuitively speaking, products traded on organized exchanges or with reference prices should have relatively low scope for quality differentiation, and other products should have relatively high scope for quality differentiation. Thus we treat com-

[14] Total factor productivity corresponds to the "overall" firm productivity $1/MC$ instead of the "processing" productivity $1/c$ in section 2.

modities in Rauch classification as quality homogeneous goods, and differentiated goods in Rauch classification as quality differentiated goods.

The second criterion that we use to identify the product quality scope is the R&D investment for different industries/products. The model implies that quality upgrading is associated with both R&D cost and component-upgrading cost. The higher are those costs in an industry, the higher should be the scope for quality differentiation. Data for component upgrading cost are hard to find, while R&D investment data are available for a wide range of industries at the U.S National Science Foundation (NSF). The data contain U.S R&D investment at the 2-digit or 3-digit SIC (Standard Industry Classification) industry level for the period 1995-1997. 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 publicly available for confidential consideration, but the data on company and other funds are available for almost all industries. The data contain 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. We 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 we use the R&D investment for different industries to classify products: If a product is in an industry with a low R&D/sales ratio, then it is classified as a quality homogeneous good; otherwise, it is classified as a quality differentiated good[15].

People may question that the Rauch classification may reflect horizontal differentiation instead of quality (vertical) differentiation, and the R&D investment may also be used to make horizontal differentiation instead of quality (vertical) differentiation for a product. This is indeed true. However, as shown in section 2.3, the level of quality (vertical) differentiation of a product is positively related to the level of horizontal differentiation of the product: products with low level of horizontal differentiation (low γ) are more likely to be quality homogeneous goods, and products with high level of horizon-

[15]We can also further classify quality differentiated goods into two subcategories in terms R&D/sales ratio, those with medium-level scope for quality differentiation and those with high scope for quality differentiation, and then test the model predictions separately with three categories of products.

tal differentiation are more likely to be quality differentiated goods. Thus even though using the Rauch classification or the R&D investment to identify product quality scope may not be accurate, they are not too bad approximation, especially when there are no other better alternatives. As will be seen in section 4, using these two criteria to classify products does result in estimates consistent with model predictions.

We 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 the Penn World Table.

3.5. Sample Selection

The benchmark sample that we use for the empirical analysis contains the above-mentioned data for the period 1997-1998. The choice of this period is based on the joint consideration of the following facts: (1) The firm productivity data is only available for 1992, 1997 and 2002, (2) the R&D data is only available for 1995-1997, and (3) there are a wide range of large tariff changes occurred around 1997 in the tariff data. In the benchmark 1997-1998 sample, export price changes and tariff changes are from 1997 to 1998, and firm productivity is for the base year 1997.[16] For R&D data, since the R&D investment may have a lag effect, we average the R&D/Sales ratios for each industry for 1995, 1996 and 1997, and use this average ratio as the indicator for R&D cost of the industry in 1997, the base year in the benchmark sample.

Panel a in table 2 lists the summary statistics for the full benchmark 1997-1998 sample, 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 in the data.[17]

[16]We have found that there is a huge change in firms' productivity from 1997 to 2002, both in the absolute magnitude and in the relative ranking. Thus we restrict our analysis to the price changes from 1997 to 1998, without extending to the years beyond (1998 to 1999, etc.); otherwise, the firm productivity data (in 1997) will not be an accurate measure for the actual firm productivity in the base year.

[17]Note that the sample size is constrained by the following operations: (i) As mentioned in the beginning of this subsection, many export transactions were dropped when we constructed the export price and their changes. (ii) When we combined the export price changes with tariff changes, firm productivity, and R&D/sales ratios, we also dropped HS6 products within which there is tariff variation, transactions conducted by firms for which we do not have the TFP data, as well as products (industries) for which we do not have the R&D data.

An observation from the table is the structure of tariff change. The table shows that, observations with tariff reduction account for 43 percent of all observations, those without any tariff change account for 53 percent, and those with tariff increase only account for 4 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.

4. Empirical Strategies and Results

We now turn to test the model predictions on tariff pass-through. Since the export prices we will get from the trade data are tariff-exclusive, we will focus on exploring how tariff changes impact the tariff-exclusive prices, i.e., tariff absorption, and how this impact depends on firm productivity and product quality. The main predictions of the model are: (i) The firm-level tariff pass-through is incomplete, that is, firms do absorb tariff change (see (13) and (14)). (ii) The absolute tariff absorption (in terms of its absolute value) positively depend on firm productivity, for both quality homogeneous goods and quality differentiated goods (see (15)). (iii) The relationship between the relative tariff absorption (tariff absorption elasticity) and firm productivity depends on the scope for quality differentiation of the product (see (16)-(18)). We test these predictions in two different ways: by pooling all products in the sample, and by dividing them into "quality homogeneous goods" and "quality differentiated goods".

4.1. All Products Pooled

In this subsection, we pool all products in the sample, without dividing them into quality homogeneous goods and quality differentiated goods, to test the model predictions. We conduct the test for two samples: the first one is the full benchmark sample for 1997-1998, and the second one is a sub-sample which only contains the U.S. exports to certain countries with large tariff changes during this period.

4.1.1. Full Sample We start with the full benchmark sample. Table 3 contains the empirical specifications and results for this full sample.

In column 1, we use the following specification to check whether the products, on average, are quality homogeneous goods or quality differentiated goods:

$$
\begin{aligned}
lnP^*_{ifc(t-1)} =& \beta lnTFP_{f(t-1)} + \delta_{ic} + \mu_{ifc(t-1)}. \\
& (- : \text{homogeneous}) \\
& (+ : \text{differentiated})
\end{aligned}
\tag{19}
$$

where $lnP^*_{ifc(t-1)}$ denotes the log tariff-exclusive price of product i exported by firm f to country c in the base period $t-1$ (1997), $lnTFP_{f(t-1)}$ represents the log total factor productivity of firm f in period $t-1$, δ_{ic} stands for a product-country fixed effect, and $u_{ifc(t-1)}$ is the error term. Here we use a product-country fixed effect to control any product-country specific determinants for export prices, so that the only variation in export prices unexplained by this fixed effect is the firm level variation. In this specification, coefficient β measures the price-productivity schedule, i.e., how export prices are related to firm productivity: if β is negative, then the products, on average, are quality homogeneous goods (see (11)); if β is positive, then the products, on average, are quality differentiated goods (see (12)). The estimated β is positive (0.06) and significant: a 10 percent increase of firm TFP leads to a 0.6 percent increase of the export price. According to the model, this positive price-productivity schedule indicates that all products on average fit the definition of quality differentiated goods.

In column 2, we use the following specification to check whether the absolute tariff absorption depends on firm productivity or not:

$$
\begin{aligned}
\Delta P^*_{ifct} =& \underset{(-)}{\beta_1 \Delta\tau_{ict}} + \beta_2 lnTFP_{f(t-1)} + \underset{(-)}{\beta_{12}}[\Delta\tau_{ict} \times lnTFP_{f(t-1)}] + \delta_i + \delta_c + \mu_{ifct},
\end{aligned}
\tag{20}
$$

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[18], $TFP_{f(t-1)}$ is the TFP of firm f in the base year

[18]Tariff changes are typically announced by governments before the actual changes occur, and export contracts are typically set before the actual transactions occur. When exporting firms learn the information of future tariff changes, they can adjust their contracts beforehand accordingly by (i) changing their

$t-1$, and δ_i and δ_c stand for the product fixed effect and the country fixed effect. We use the product fixed effect and the country fixed effect to control for any product-specific shocks and country-specific shocks (such as exchange rate changes and demand changes) on export price changes[19]. The reason for using these two fixed effects instead of using a product-country fixed effect is that the latter will absorb the effect of tariff change, which is product-country specific (since the tariff change is just for one period, from 1997 to 1998). In this specification, the coefficient of the tariff change term, 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), and the estimated one is indeed negative (though insignificant) in column 2; 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. According to (15), this coefficient should be negative[20], and the estimated one is indeed negative (though insignificant) in column 2. 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 an unambiguous prediction about the sign of this direct effect, captured by coefficient β_2.

In cloumn 3, we use the following regression to estimate tariff absorption elasticity:

$$\Delta lnP^*_{ifct} = \underset{(-)}{\beta}\Delta ln(1+\tau_{ict}) + \delta_i + \delta_c + \mu_{ifct}, \tag{21}$$

Notice that we now have logs for both the price change and the tariff change. Thus

export prices for transactions that will occur when the tariffs change (contemporaneous effect), and/or (ii) change their export prices for transactions that will occur before the tariffs change (lead effect), if they want to smooth their price changes. Here the coefficient for the tariff change term, $\Delta\tau_{ict}$, only captures the contemporaneous effect but not the lead effect, and thus should be lower than the total effect of tariff changes on price changes. We could add another term, $\Delta\tau_{ic(t+1)}$, to capture the lead effect.

[19]Note that since the specification that we use is first order difference, we have already removed all time-invariant fixed effects (including product, firm, country, product-firm, product-country, firm-country, and product-firm-country fixed effect) on price levels. The fixed effects here and those in the regressions hereafter refer to fixed effects on price changes.

[20]Notice that a negative coefficient β_{12} means that, for firms with high productivity, the impact of tariff change on tariff-exclusive price is even more negative, i.e., higher in terms of absolute value (indicated by (15)). This is due to the fact $\partial p^*/\partial\tau^f < 0$.

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.[21] Again here we use both product and country fixed effects. According to (14), the tariff absorption elasticity β should be negative. The estimated overall tariff absorption elasticity is indeed negative (-0.87) and significant. This indicates that the firm-level tariff absorption does exist: on average exporting firms absorb 87 percent of the tariff reduction by increasing their tariff-exclusive prices. In other words, the firm-level tariff pass-through is indeed incomplete: only 13 percent of the tariff reduction is passed on to consumers as lower consumer prices.

You may wonder why the tariff absorption elasticity (in terms of absolute value) is so high comparing to the estimates in previous studies at the industry level[22]. There are two possible reasons for this. First, the tariff absorption we get here is at the firm-level and is for incumbent firms after tariff reductions. As shown in the model, these firms not only increase their markups but also upgrade their product quality in response to tariff reductions, and hence their price increase is high. Second, according to the model, the new entrants caused by tariff reductions (which are less productive than incumbents) may have lower-than-average prices since they produce lower quality goods, and thus the average industry-level prices after tariff reductions only increase by a smaller magnitude, which is consistent with the previous smaller estimates at the industry level.

In column 4, we add firm productivity and its interaction with the relative tariff change to estimate its direct effect on price change and its impact on tariff absorption:

$$
\begin{aligned}
\Delta lnP^{*}_{ifct} = & \underset{(-)}{\beta_1 \Delta ln(1+\tau_{ict})} + \beta_2 TFPH_{f(t-1)} + \beta_{12}[\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}] \\
& \qquad\qquad\qquad\qquad (- : \text{homogeneous}) \\
& \qquad\qquad\qquad\qquad (\pm : \text{modestly differentiated}) \\
& \qquad\qquad\qquad\qquad (+ : \text{highly differentiated}) \\
& + \delta_i + \delta_c + \mu_{ifct}
\end{aligned} \tag{22}
$$

[21] 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. In specification (20) we have the absolute change of net tariff rate since that is equivalent to absolute change of gross tariff rate, i.e., $\Delta\tau_{ict} = \Delta(1+\tau_{ict})$.

[22] Recall that in Feenstra (1989), the tariff absorption in the automobile industry is only 40 percent. In Kreinin (1961), the average tariff absorption in all industries is higher at around 67 percent, but still much lower than the estimate in this paper.

This specification is a counterpart of (20), 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 estimation is indeed negative (-1.27) and significant. A tariff absorption elasticity less than -1 implies that, when low productivity firms face a tariff reduction, they increase their tariff-exclusive prices so much that the tariff-inclusive consumer prices actually increase instead of decreasing. This is known as the "Metzler Paradox". The possible reason again lies in quality upgrading: the initial product quality for low productivity firms is low; when they face a tariff reduction, they upgrade their product quality by a significant relative magnitude, which leads to a high increase in their tariff-exclusive prices. Thus, quality upgrading provides a reasonable explanation for the "Metzler Paradox".

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 terms of its 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 quality homogeneous goods (by (16)), ambiguous for quality differentiated good with medium-level scope for quality differentiation (by (17)), but positive for quality differentiated goods with high scope for quality differentiation (by (18)).[23] The estimated β_{12} is positive (0.83) and significant, indicating that high productivity firms actually have lower (in terms of its absolute value) tariff absorption elasticity, which is -0.44 ($-1.27 + 0.83 = -0.44$). This is consistent with the model prediction for quality differentiated

[23] Again, notice that the signs of these coefficients are seemingly opposite to, but actually consistent with, the expressions and word interpretations in terms of absolute values ((16)-(18)). This is again caused by the fact $\partial p^*/\partial \tau^f < 0$.

goods with high scope for quality differentiation. Thus, on average the products in the full sample have a relatively high scope for quality differentiation.

In column 5, we add two other control variables, exchange rate changes and GDP changes of the destination countries:

$$\begin{aligned}
\Delta lnP^*_{ifct} =& \underset{(-)}{\beta_1 \Delta ln(1+\tau_{ict})} + \beta_2 TFPH_{f(t-1)} + \underset{\substack{(-\,:\,\text{homogeneous})\\(\pm\,:\,\text{modestly differentiated})\\(+\,:\,\text{highly differentiated})}}{\beta_{12}[\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}]} \\
&+ \underset{(-)}{\beta_3 \Delta lnXR_{c(t-1)}} + \underset{(+)}{\beta_4 \Delta lnGDP_{ct}} + \delta_i + \mu_{ifct},
\end{aligned} \tag{23}$$

Notice that here the change of log exchange rate (measured as units of foreign currency per U.S. dollar), $\Delta lnXR_{c(t-1)}$, is one period ahead of the tariff change[24]. A dollar appreciation should cause U.S. exporting firms to lower their export prices denominated in U.S. dollars[25], and thus β_3 should be negative. The change of log GDP of the destination country, $\Delta lnGDP_{ct}$, is used to control for the change of market demand. An increase of the market demand should push up export prices, and thus β_4 should be positive. Since these two variables are country specific, we drop the country fixed effect and only keep the product fixed effect in the regression. The estimates for these two controls are not significant[26], 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 produc-

[24] We use the exchange rate changes one-period ahead, because exchange rate changes are not announced beforehand, and thus it will take exporting firms some time to adjust their contracts, which are typically set before the actual transactions occur. Hence exchange rate changes typically have a lag effect on price changes, as shown in the exchange rate pass-through literature. This is quite different from the impacts of tariff changes on price changes, where there are a contemporaneous effect and a lead effect, as discussed in footnote 17.

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

[26] As you will see, even though we get significant tariff pass-through elasticities in almost all regressions throughout the paper, we do not get significant exchange rate pass-through elasticity in any regression. Two possible explanations are: (1) As we indicated earlier, exchange rate pass-through has a lag effect, but the length of the lag effect depends on the nature of contracts of trade transactions, which is very complicated in reality, and thus our specification of one-period lag effect may be inaccurate. (2) In many cases firms regard exchange rate changes as temporary changes, but tariff changes as permanent changes. Thus firms' response to exchange rate changes is less prominent than their response to tariff changes.

tivity firms. The lower (in terms of its absolute value) elasticity for higher productivity firms is still consistent with the model prediction for products with high scope for quality differentiation.

In cloumn 6, we add the market size and the initial tariff of the destination country, as well as their interaction with the relative tariff change, to estimate their impacts on price change and tariff absorption:

$$
\begin{aligned}
\Delta lnP^*_{ifct} =& \underset{(-)}{\beta_1 \Delta ln(1+\tau_{ict})} + \beta_2 TFPH_{f(t-1)} + \beta_{12}[\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}] \\
& \qquad\qquad\qquad\qquad (-: \text{homogeneous}) \\
& \qquad\qquad\qquad\qquad (\pm: \text{modestly differentiated}) \\
& \qquad\qquad\qquad\qquad (+: \text{highly differentiated}) \\
& + \underset{(-)}{\beta_3 \Delta lnXR_{c(t-1)}} + \underset{(+)}{\beta_4 \Delta lnGDP_{ct}} \\
& + \beta_5 ln(1+\tau_{ic(t-1)}) + \beta_{15}[\Delta ln(1+\tau_{ict}) \times \ln(1+\tau_{ic(t-1)})] \\
& + \beta_6 lnGDP_{c(t-1)} + \beta_{16}[\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}] + \delta_i + \mu_{ifct},
\end{aligned}
\tag{24}
$$

where $\tau_{ic(t-1)}$ is the initial tariff rate in the base year, and $GDP_{c(t-1)}$ is GDP of country c in the base year, which measures its market size in the base year. The model shows that these two factors do affect price changes and tariff absorption, as indicated by (8) and (14). However, the model does not have an unambiguous prediction about the signs of their impacts on price changes (captured by coefficients β_5 and β_6), or the signs of their impacts on tariff absorption (captured by coefficients β_{15} and β_{16}). Here we add these terms as we wanted to empirically check the nature and significance of their impacts. The estimates show that none of these impacts is significant. Notice that in this specification the estimate for the coefficient of the tariff change term (-4.96) measures the tariff absorption elasticity for low productivity firms ($TFPH = 0$) exporting to a country with a hypothetical tariff rate for the product ($ln(1+\tau) = 0$) and a hypothetical GDP ($lnGDP = 0$), and thus its magnitude is meaningless. However, the positive coefficient for the interaction term between the relative tariff change and the high TFP dummy (0.83) still shows that firms with high productivity have lower (in terms of its absolute value) tariff absorption elasticity, which is consistent with the model prediction for products with high scope for quality differentiation.

4.1.2. Sub-sample with Large Tariff Changes Next, we conduct the same analysis as above for a sub-sample that only includes countries with large tariff changes for certain products during the period 1997-1998. More specifically, we only include 38 countries for which there is at least one HS6 industry with tariff change higher than 5 percentage points; but for each of these countries, we keep all industries no matter whether they have large tariff change or not. The purpose of choosing this sample is to ensure that there are enough observations with large 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. The countries contained in the sub-sample are listed in table 4.

People may wonder whether the construction of the sub-sample containing only countries with large tariff changes will lead to selection bias. To address this concern, we compare the full benchmark sample and the sub-sample by including the summary statistics for the sub-sample in panel b of table 2. The comparison between these two samples shows that even though the sub-sample only contains two thirds of the countries (38 vs. 61) in the full sample, all the other indicators in the two samples are pretty close to each other, which indicates that the sub-sample is quite representative for the full sample. This is because that the countries contained in the sub-sample not only include all the large 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.).

Table 5 contains the regression results for this sub-sample. This table shows the qualitatively same results as those in table 3. First, there is a positive and significant price-productivity schedule (with estimate 0.05), which shows that all products on average fit the definition of quality differentiated goods. Second, the firm-level tariff pass-through is indeed incomplete, and the overall tariff absorption elasticity is -0.65, as shown in column 3. Third, the absolute magnitude of tariff absorption (in terms of absolute value) is positively related to firm productivity, as shown by the negative (though insignificant) estimate for the interaction term between the absolute tariff change and firm TFP in column 2. Next, tariff absorption elasticity (in terms of absolute value) is higher for low productivity firms, and lower for high productivity firms, as shown by the positive and significant estimates (0.90) for the interaction term between the relative tariff change and the high TFP dummy in columns 4-6. This is consistent with the model predictions for products with high scope for quality differentiation. Finally, the impacts of initial tariff rate and market size 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 (1) firm-level tariff absorption does exist, i.e., firm-level tariff pass-through is indeed incomplete; (2) all products on average fit the definition of quality differentiated goods, as they have a positive price-productivity schedule; and (3) tariff absorption elasticity (in terms of absolute value) is higher for low productivity firms and lower for high productivity firms, which is consistent with the model prediction for products with high scope for quality differentiation.

4.2. Quality Homogeneous Goods vs. Quality Differentiated Goods

In this subsection we divide all products in the benchmark full sample into two groups, "quality homogeneous goods" and "quality differentiated goods", and run the regressions specified above separately for the two groups. As mentioned in section 3, we classify the products by two criteria: Rauch classification and R&D/sales ratio.

4.2.1. In terms of Rauch Classification The first criterion that we use to classify products is the Rauch classification: We treat commodities in terms of the Rauch classification as quality homogeneous goods, and treat differentiated goods in terms of Rauch classification as quality differentiated goods. Among the 84,902 observations (product-firm-country-year cells) in the benchmark full sample, only 6,171 belong to quality homogeneous goods, and the other 65,277 belong to quality differentiated goods. Table 6 and table 7 present the regression results for these two groups, respectively.

In table 6 (for commodities), the slope for the price-productivity schedule is not significant and even not negative, as shown in column 1. This indicates that it may not be accurate to treat all commodities in terms of the Rauch classification as quality homogeneous goods. The relationship between absolute magnitude of tariff absorption and firm productivity is not significant, as shown in column 2. Column 3 shows that the overall tariff absorption elasticity is indeed negative and significant (-1.21), indicating that firm-level tariff pass-through is indeed incomplete[27]. The estimates in columns 4-6 for the interaction term between the relative tariff change and the high TFP dummy are all negative (though insignificant), which shows that high productivity firms have a higher (but not significant) tariff absorption elasticity (in terms of its absolute value) than low productivity firms. This is qualitatively consistent with the model prediction for quality homogeneous goods. The impacts of initial tariff rate and market size on tariff absorption are again insignificant.

In table 7 (for differentiated products), we do find a positive and significant price-productivity schedule, as shown in column 1, which shows that differentiated products in terms of the Rauch classification fit the definition of quality differentiated goods. Column 2 shows that the absolute magnitude of tariff absorption (in terms of its absolute value) is positively (though not significantly) related to firm productivity, which is consistent with model predictions. Column 3 shows that the overall tariff absorption elasticity for this group is indeed negative and significant (-0.80), which implies that firm level tariff pass-through is indeed incomplete. Column 4 shows that the tariff absorption elasticity is higher (in terms of its absolute value) for low productivity firms (-1.30), and lower (in terms of its absolute value) for high productivity firms ($-1.30 + 1.04 = -0.26$), which is consistent with the model prediction for products with high scope for quality differentiation. 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 initial tariff rate and market size on tariff absorption are insignificant.

[27]A surprising finding here is that the tariff absorption elasticity is higher than 1 in terms of its absolute value, that is, "Metzler Paradox" also exists for commodities, for which there should be no large quality adjustment in response to tariff change.

*4.2.2. **In terms of R&D/Sales Ratio*** The second criterion that we use to classify products is the R&D/sales ratio for different industries/products. We treat goods with R&D/sales ratios lower than the 25th percentile of R&D/sales ratios for all products in the full benchmark sample as quality homogeneous goods, and other goods as quality differentiated goods. The reason for using the 25th percentile as the cutoff is that, comparing to the mean or median, this cutoff leads to 15,408 observations in the group of quality homogeneous goods and 69,494 observations in the group of quality differentiated goods, which are close to sample sizes of the two groups under the Rauch classification[28]. Table 8 and table 9 present the regression results for these two groups, respectively.

In table 8 (for products with low R&D/sales ratios), we did not find a negative and significant price-productivity schedule, as shown in column 1, which indicates that it may not be accurate to treat all products with low R&D/sales ratios as quality homogeneous goods. Again the absolute magnitude of tariff absorption (in terms of its absolute value) is positively (though not significantly) related to firm productivity, as shown by the negative estimate for the interaction term between tariff change and TFP in column 2. Column 3 shows that the overall tariff absorption elasticity is not significant for this group of goods. The estimates in columns 4-6 for the interaction term between the relative tariff change and the high TFP dummy are all insignificant, which shows that the impact of firm productivity on tariff absorption is insignificant for this group of goods. The last column shows that the impacts of initial tariff rate and market size on tariff absorption are also insignificant.

In table 9 (for products with high R&D/sales ratios), we do have a positive and significant price-productivity schedule, as shown in column 1, which shows that products with high R&D/sales ratios do fit the definition of quality differentiated goods. Again column 2 shows that the absolute magnitude of tariff absorption (in terms of its absolute value) is positively (though not significantly) related to firm productivity, which is consistent with the model prediction. Column 3 shows that the overall tariff absorption elasticity is -1.01 and significant for this group, which again confirms the incompleteness

[28]The correlation between these two classifications is 0.30.

of firm-level tariff pass-through and the "Metzler Paradox". Column 4 shows that the tariff absorption elasticity is higher (in terms of its absolute value) for low productivity firms (-1.60), and lower (in terms of its absolute value) for high productivity firms ($-1.60 + 1.23 = -0.37$), which is consistent with the model prediction for products with high scope for quality differentiation. The positive estimates for the interaction term between the relative tariff change and the high TFP dummy in columns 5-6 show the same conclusion. Again the last column shows that the impacts of initial tariff rate and market size on tariff absorption are insignificant.

In short, the regression results presented in this subsection show that the inverse relationship between tariff absorption elasticity and productivity is more pronounced for quality differentiated goods and non-existent for quality homogeneous goods, which is consistent with the model. Note that the group of quality homogeneous goods that we got in terms of the two criteria (the Rauch classification and the R&D/Sales ratios) does not fully fit the definition of quality homogeneous goods, since they do not have a significant negative price-productivity schedule. Thus, even though we did not find a significant positive relationship between tariff absorption elasticity and productivity for this group of products (as the model predicts), we attribute this to the empirical measurement error instead of the failure of the model.

5. Conclusions

This paper explores the incompleteness of tariff pass-through at the firm level, as well as its dependence on firm heterogeneity in productivity and product differentiation in quality. On the theoretical side, we use an extended version of the Melitz and Ottaviano (2008) model and show that, when exporting firms face a foreign tariff change, they will absorb part of the tariff change by adjusting both their markups and their product quality, which leads to an incomplete tariff pass-through. Moreover, tariff absorption elasticity (in terms of its absolute value) and firm productivity are negatively correlated for products with high scope for quality differentiation, but positively correlated for quality homogeneous goods.

On the empirical side, we use the U.S. transaction-level export data and plant-level manufacturing data, and find evidence for the predictions of the model. The firm-level tariff absorption elasticity is -0.87 on average. Pooled regressions reveal that the tariff absorption elasticity is higher (in terms of its absolute value) for lower productivity firms (-1.27) and lower for high productivity firms (-0.44). Estimation done separately on quality differentiated goods and quality homogeneous goods finds that the inverse relationship between tariff absorption elasticity and productivity is more pronounced for quality differentiated goods and non-existent for quality homogeneous goods, which is consistent with the model.

References

Bagwell, K. and Staiger, R. 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. (2008), "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trades Goods", forthcoming in Dunne, T., Jensen, J. B., and Roberts, M. J., eds *Producer Dynamics: New Evidence from Micro Data*, University of Chicago Press.

Broda, C., Limão, 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 Volume 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.

Tables

Table 1. Summary of Model Predictions for Comparative Statics: Products with Different Scopes for Quality Differentiation

Item	Comparative Statics	Low Scope $\left(\frac{2\theta}{L^f}+b\right)\tau^f > \gamma$	Medium Scope $\left(\frac{2\theta}{L^f}+b\right)\tau^f < \gamma$	High Scope $\left(\frac{2\theta}{L^f}+b\right)\tau^f \ll \gamma$
Price and	$\partial p^*/\partial(\frac{1}{c})$	−	+	+
	$\partial p_q^*/\partial(\frac{1}{c})$	−	−	−
Productivity	$\partial p_z^*/\partial(\frac{1}{c})$	+	+	+
Absolute Tariff	$\partial p^*/\partial\tau^f$		−	
Absorption	$\partial p_q^*/\partial\tau^f$		−	
	$\partial p_z^*/\partial\tau^f$		−	
Relative Tariff	$\Theta^* \equiv \frac{\partial p^*}{\partial\tau^f}\frac{\tau^f}{p^*}$		−	
Absorption	$\Theta_{p_q^*} \equiv \frac{\partial p_q^*}{\partial\tau^f}\frac{\tau^f}{p_q^*}$		−	
	$\Theta_{p_z^*} \equiv \frac{\partial p^*}{\partial\tau^f}\frac{\tau^f}{p_z^*}$		−	
Absolute Tariff	$\frac{\partial\lvert\partial p^*/\partial\tau^f\rvert}{\partial(\frac{1}{c})}$		+	
Absorption and	$\frac{\partial\lvert\partial p_q^*/\partial\tau^f\rvert}{\partial(\frac{1}{c})}$		0	
Productivity	$\frac{\partial\lvert\partial p_z^*/\partial\tau^f\rvert}{\partial(\frac{1}{c})}$		+	
Relative Tariff	$\frac{\partial\lvert\Theta^*\rvert}{\partial(\frac{1}{c})}$	+	±	−
Absorption and	$\frac{\partial\lvert\Theta_{p_q^*}\rvert}{\partial(\frac{1}{c})}$	+	+	+
Productivity	$\frac{\partial\lvert\Theta_{p_z^*}\rvert}{\partial(\frac{1}{c})}$	−	−	−

Table 2. Summary Statistics for Two Samples

	a. Full Sample			b. Sub-sample		
No. of HS2	85			85		
No. of HS6	2,005			1,979		
No. of HS10	2,735			2,679		
No. of Firms	14,404			13,275		
No. of Countries	61			38		
TV_{t-1}	5.28×10^{10}			4.26×10^{10}		
Variables	No. of Obs.	Mean	Std.Dev.	No. of Obs.	Mean	Std.Dev.
ΔlnP_{ifct}	84,902	-0.010	1.474	65,227	-0.009	1.431
$\Delta\tau_{ict}$: all	84,902	-0.006	0.023	65,227	-0.008	0.026
$\Delta\tau_{ict} < 0$	36,175(43%)	-0.019	0.028	34,612(53%)	-0.019	0.028
$\Delta\tau_{ict} = 0$	45,125(53%)	0	0	27,047(41%)	0	0
$\Delta\tau_{ict} > 0$	3,602(4%)	0.035	0.034	3,568(6%)	0.035	0.035
$lnTFP_{f(t-1)}$	84,902	1.888	0.577	65,227	1.889	0.581

Notes:

(1) Full Sample: 1997-1998. (Benchmark Sample)

(2) Sub-sample: 1997-1998, countries with large tariff change (higher than 5 percentage points) in at least one HS6 industry.

Table 3. Tariff Absorption: Full Sample, All Products

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		-516 (33000)				
$lnTFP_{f(t-1)}$	0.06*** (0.01)	1,500*** (548)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-1700 (16000)				
$\Delta ln(1+\tau_{ict})$			-0.87** (0.35)	-1.27*** (0.42)	-0.89** (0.38)	-4.96 (5.1)
$TFPH_{f(t-1)}$				0.02** (0.01)	0.02** (0.01)	0.02** (0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.83* (0.50)	0.84* (0.50)	0.83* (0.50)
$\Delta lnXR_{c(t-1)}$					0.03 (0.07)	0.03 (0.07)
$\Delta lnGDP_{ct}$					-0.0002 (0.05)	-0.01 (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	product +country	product +country	product	product
No. of Obs.	84,902	84,902	84,902	84,902	84,902	84,902
R^2	0.81	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 4. Countries in the Sub-sample: with Large 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 5. Tariff Absorption: Sub-sample (with Large Tariff Change), All Products

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		-2,200 (38000)				
$lnTFP_{f(t-1)}$	0.05*** (0.01)	1,800** (695)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-620 (973)				
$\Delta ln(1+\tau_{ict})$			-0.65* (0.35)	-1.08** (0.43)	-0.75** (0.38)	-6.96 (5.3)
$TFPH_{f(t-1)}$				0.03*** (0.01)	0.03** (0.01)	0.03** (0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.90* (0.50)	0.90* (0.50)	0.90* (0.50)
$\Delta lnXR_{c(t-1)}$					0.04 (0.08)	0.04 (0.08)
$\Delta lnGDP_{ct}$					-0.07 (0.10)	-0.07 (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 6. Tariff Absorption: Benchmark Sample, Commodities — In terms of the Rauch Classification

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		231 (7,700)				
$lnTFP_{f(t-1)}$	0.23 (0.15)	-37.4 (207)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		47.5 (6,100)				
$\Delta ln(1+\tau_{ict})$			-1.21** (0.60)	-0.73 (0.72)	-0.67 (0.65)	22.4* (13.6)
$TFPH_{f(t-1)}$				0.007 (0.02)	0.008 (0.02)	0.008 (0.02)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				-1.14 (0.92)	-1.10 (0.91)	-1.18 (0.92)
$\Delta lnXR_{c(t-1)}$					0.19 (0.17)	0.17 (0.18)
$\Delta lnGDP_{ct}$					0.16 (0.10)	0.15 (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 7. Tariff Absorption: Benchmark Sample, Differentiated Products — In terms of the Rauch Classification

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		-1,300 (40,000)				
$lnTFP_{f(t-1)}$	0.05*** (0.01)	-1,600 (592)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-1,300 (18,000)				
$\Delta ln(1+\tau_{ict})$			-0.80** (0.38)	-1.30*** (0.46)	-0.93** (0.41)	-6.73 (5.37)
$TFPH_{f(t-1)}$				0.02** (0.01)	0.2** (0.01)	0.02** (0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				1.04* (0.54)	1.05* (0.54)	1.04* (0.54*)
$\Delta lnXR_{c(t-1)}$					0.03 (0.07)	0.02 (0.08)
$\Delta lnGDP_{ct}$					-0.02 (0.06)	-0.03 (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.

Table 8. Tariff Absorption: Benchmark Sample, Quality Homogeneous Goods — With Low R&D/Sales Ratios

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		-38 (528)				
$lnTFP_{f(t-1)}$	0.24 (0.25)	-0.86 (19)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-47 (550)				
$\Delta ln(1+\tau_{ict})$			-0.60 (0.49)	-0.64 (0.56)	-0.43 (0.43)	3.30 (7.26)
$TFPH_{f(t-1)}$				0.006 (0.017)	0.006 (0.017)	0.006 (0.017)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				0.08 (0.59)	0.10 (0.59)	0.11 (0.59)
$\Delta lnXR_{c(t-1)}$					0.32** (0.15)	0.33 ** (0.15)
$\Delta lnGDP_{ct}$					0.05 (0.10)	0.05 (0.10)
$ln(1+\tau_{ic(t-1)})$						0.02 (0.16)
$lnGDP_{c(t-1)}$						-0.002 (0.008)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						3.97 (4.49)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						-0.19 (0.28)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	15,408	15,408	15,408	15,408	15,408	44,167
R^2	0.82	0.01	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 9. Tariff Absorption: Benchmark Sample, Quality Differentiated Goods — With High R&D/Sales Ratios

Dependent Variable Regressors	$lnP^*_{ifc(t-1)}$ (1)	ΔP^*_{ifct} (2)	ΔlnP^*_{ifct} (3)	ΔlnP^*_{ifct} (4)	ΔlnP^*_{ifct} (5)	ΔlnP^*_{ifct} (6)
$\Delta\tau_{ict}$		-3,900 (24,000)				
$lnTFP_{f(t-1)}$	0.03** (0.01)	1,500** (609)				
$\Delta\tau_{ict} \times lnTFP_{f(t-1)}$		-3,400 (29,000)				
$\Delta ln(1+\tau_{ict})$			-1.01** (0.46)	-1.60*** (0.56)	-1.15** (0.50)	-8.90 (7.10)
$TFPH_{f(t-1)}$				0.03** (0.01)	0.03** (0.01)	0.03** (0.01)
$\Delta ln(1+\tau_{ict}) \times TFPH_{f(t-1)}$				1.22* (0.66)	1.23* (0.66)	1.23* (0.66)
$\Delta lnXR_{c(t-1)}$					-0.003 (0.081)	-0.013 (0.082)
$\Delta lnGDP_{ct}$					-0.008 (0.06)	-0.018 (0.06)
$ln(1+\tau_{ic(t-1)})$						0.13 (0.15)
$lnGDP_{c(t-1)}$						0.002 (0.005)
$\Delta ln(1+\tau_{ict}) \times ln(1+\tau_{ic(t-1)})$						3.52 (4.38)
$\Delta ln(1+\tau_{ict}) \times lnGDP_{c(t-1)}$						0.28 (0.26)
Fixed Effects	product ×country	product +country	product +country	product +country	product	product
No. of Obs.	69,494	69,494	69,494	69,494	69,494	69,494
R^2	0.79	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.

Essay 2. Tariff Pass-through and Market Structure§

Rodney Ludema†
Georgetown University

Zhi Yu‡
Georgetown University

July 2011

Abstract: This paper studies how market structure impacts tariff pass-through. We explore this with a model in which both export firms and import firms have some market power. If foreign export firms that sell in the domestic market have high market power, they will get high markups in price bargaining, and hence absorb more of the tariff change by markup adjustment, and pass less of the tariff change to domestic import firms. If domestic import firms have high market power, they will force foreign export firms to lower markups in price bargaining on the one hand; On the other hand, they also have a high ability to transfer their costs to domestic consumers, and thus export firms will set high markups in price bargaining. The net impact on the actual markups of foreign export firms, and hence the net impact on their tariff absorption and pass-through, depends on the comparison of these two opposite effects. Thus, the relationship between the market power of import firms and tariff pass-through is ambiguous. We use the US transaction-level import data from 1995 to 1999, which is the applied period of Uruguay Round, to test these predictions. The results show that these predictions are supported by the data.

Key Words: Tariff Pass-through, Market Structure, Markups
JEL Numbers: F1, D4, L1

---

§ The authors thank J. Bradford Jensen and Anna Maria Mayda for helpful insights and comments. Zhi Yu also thanks Lynn Riggs of the Census Bureau for technical support and Jim Davis of the NBER for timely disclosure of the data analysis. Support for this research at the Census Bureau RDC from NSF (ITR-0427889) is also gratefully acknowledged. The research in this paper was conducted while Zhi Yu was a Special Sworn Status researcher at the U.S. Census Bureau, Center for Economic Studies. Any opinions and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information is disclosed.

† Georgetown University, Department of Economics, 37th and O Streets, Washington, DC 20057, U.S.A. E-mail: ludemar@georgetown.edu.

‡ Georgetown University, Department of Economics, 37th and O Streets, Washington, DC 20057, U.S.A. E-mail: zy24@georgetown.edu.

1. Introduction

Motivation This paper studies how market structure impacts tariff pass-through. The paper derives its motivation from the literature on incompleteness of tariff pass-through. As is well known, when the tariff rates of a large country increase, foreign export firms may absorb part of the tariff increase by lowering their tariff-exclusive export prices[29], and only pass the rest of the tariff increase to domestic import firms, so that the impact of tariff changes on domestic prices and market demand is mitigated. Thus tariff increase improves terms of trade of the home country. Similarly, domestic import firms may also adjust consumer prices, and only pass part of the tariff increase they receive to domestic consumers, so that the impact of tariff changes on consumer prices and final market demand is further mitigated; but the price adjustment of domestic import firms will in turn affect how much of the tariff increase that foreign export firms will pass to domestic import firms. Incomplete tariff pass-through is the source of the terms-of-trade effect of tariffs, which is the basis for the optimal tariff argument and a driving force for international trade agreements, as shown in Edgeworth (1894), Broda, Limão and Weinstein (2008), Bagwell and Staiger (2009), and Ludema and Mayda (2010).[30]

The price adjustment of foreign export firms and domestic import firms are due to either (1) cost change, which could occur with either perfectly or imperfectly competitive markets, or (2) markup adjustment, which could only occur with imperfectly competitive markets. With imperfectly competitive markets, markup adjustment is an important source of price adjustment. However, the magnitude of markups of export firms and import firms is affected by market structure, i.e., the competition between export firms and that between import firms. Thus one might wonder how market structure impacts the tariff pass-through to import prices.

[29]For this reason we also refer to incomplete tariff pass-through as "tariff absorption". Graphically, this is represented by the downward movement along the upward-slopping foreign export supply curve of the home country.

[30]The optimal argument says that, 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. Broda, Limão and Weinstein (2008) examine this with the tariff schedules of non-WTO countries; Bagwell and Staiger (2009) consider this with changes in the tariff schedules of recent WTO accession countries; Ludema and Mayda (2010) explore this with MFN tariffs set by existing WTO members.

Literature Feenstra (1989) has a classic theoretical model on how tariff pass-through is determined, which he uses to estimate tariff pass-through to US imports of Japanese trucks. Rezitis and Brown (1999) use the model to estimate tariff pass-through to US imports of tobaccos. Mallick and Marques (2007) use the model to estimate tariff pass-through to Indian imports of a large variety of goods. Feenstra's model is characterized by Betrand duoploy – one foreign export firm competing in price with a domestic producer, with their products imperfect substitutes. He derives an equation which shows that import prices are determined by foreign producer costs, prices of the domestic rivals, domestic demand, exchange rates and tariffs. Then he uses this equation to estimate tariff pass-through elasticities. However, Feenstra does not analyze the case with multiple export firms, and how the competition between them affects tariff pass-through. In addition, he does not study the role of import firms in tariff pass-through, either.

Francois and Wooton (2006) consider the interaction between perfectly competitive export firms and oligopoly import firms. They do analyze how market power of import firms affects tariff pass-through to import quantities (not to import prices), but they do not study the case in which export firms also have some market power, and how this affects tariff pass-through.

Horn and Wolinsky (1988) analyze a duoploy in which firms acquire inputs through bilateral monopoly relations with suppliers. They combine a bargaining model with a duopoly model to examine how input prices are affected by the structures of the upstream and downstream industries. Durham (2006) studies the double marginalization problem between a monopoly upstream firm and a monopoly/competitive downstream firm. However, Neither of these two studies extends the analysis to tariff pass-through from upstream export firms to downstream import firms.

Contribution This paper has two contributions to the literature.

First, we theoretically analyze how market structure impacts tariff pass-through in a more general and more realistic framework: both export and import firms have some but limited market power. We study how the degree of their market power impacts tariff pass-through. The model predicts that tariff pass-through is negatively related to the market power of export firms, but is ambiguously related to the market power of import firms. The intuition is as follows. If foreign export firms that sell in the domestic market have high market power, they will get high markups in price bargaining, and hence absorb more of the tariff change by markup adjustment, and pass less of the tariff change to domestic import firms. If domestic import firms have high market power, they will force foreign export firms to lower markups in price bargaining on the one hand; On the other hand, they also have a high ability to transfer their costs to domestic consumers, and thus export firms will set high markups in price bargaining. The net impact on the actual markups of foreign export firms, and hence the net impact on their tariff absorption and pass-through, depends on the comparison of these two opposite effects. Thus, the relationship between the market power of import firms and tariff pass-through is ambiguous, and should be investigated empirically.

Second, we use a newly-developed dataset, the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD) for U.S. imports, to test the model predictions regarding the relationship between market structure and tariff pass-through. This dataset contains all the necessary information to calculate import prices, tariffs, and market power of export and import firms (measured by the concentration of export and import firms). Thus it is very good to be used to test how market structure affects tariff pass-through. The estimation results support the predictions of the model.

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 contains the empirical specification. Section 4 describes the dataset. Section 5 includes the estimation results. Conclusions and forward research are included in section 6.

2. The Model

Environment Following Horn and Wolinsky (1988), we assume that the import market of a product (either an intermediate input or a consumption good) consists of M upstream foreign export firms, indexed by $m \in \{1, 2, ..., M\}$, and N downstream domestic import firms, indexed by $n \in \{1, 2, ..., N\}$. Domestic import firms could be either producers (if the imports are intermediate inputs) or retailers (if the imports are consumption goods), and each of them will eventually provide a differentiated variety of the product to domestic consumers. To account for both these two cases, we assume that the technology of import firm n displays constant return to scale: import quantity q_n^u generates output $q_n^d = q_n^u \equiv q_n$, where the superscripts u and d denote upstream and downstream, respectively, and could be omitted. If its import price is p_n^u and its final sale price is p_n^d, then the profit of the import firm is

$$\Pi_n^d = (p_n^d - p_n^u)q_n. \tag{25}$$

Foreign export firms could also be either producers or retailers of the product, and their unit cost is a constant, b, which is the same across export firms. They face an ad valorem tariff, τ, imposed by the domestic government. The profit of the export firm that supplies the product to import firm n is

$$\Pi_n^u = \left(\frac{p_n^u}{1+\tau} - b\right) q_n. \tag{26}$$

The events in the industry take place in two stages. In the first stage, export firms and import firms bargain with each other in the upstream market over the import prices of the product. In the second stage, import firms interact in the downstream market, deciding on the quantities they will produce and thus the quantities they will import. The two-stage structure captures the situation in which input prices are determined for a relatively long period while production or purchasing decisions are made for a relatively shorter period. As usual, we will solve the problem in the downstream market first, and then use backward induction to solve the problem in the upstream market.

Problem in Downstream Market In the downstream market we assume import firms are Cournot quantity setters. The inverse demand for the variety provided by firm n is

$$p_n^d = a - c\sum_{j\neq n} q_j - q_n, \tag{27}$$

where $c \in (0,1)$ measures the substitutability between different varieties of the product provided by different import firms[31]. The maximization problem of import firm n is

$$\max_{q_n} \Pi_n^d = (p_n^d - p_n^u)q_n = \left[a - c\sum_{j\neq n} q_j - q_n - p_n^u\right] q_n. \tag{28}$$

Solving this problem[32], we get the following equilibrium quantity as a function of upstream import prices

$$q_n(p_n^u, p_{-n}^u) = \frac{a(2-c) - [2+(N-2)c]p_n^u + c\sum_{j\neq n} p_j^u}{(2-c)[2+(N-1)c]}, \tag{29}$$

and the equilibrium profit

$$\Pi_n^d(p_n^u, p_{-n}^u) = \left[\frac{a(2-c) - [2+(N-2)c]p_n^u + c\sum_{j\neq n} p_j^u}{(2-c)[2+(N-1)c]}\right]^2 = [q_n(p_n^u, p_{-n}^u)]^2, \tag{30}$$

where $p_{-n}^u \equiv \left\{p_j^u\right\}_{j\neq n}$.

Problem in Upstream Market In the upstream market, foreign export firms and domestic import firms bargain over the import prices of the product. If an export firm and import firm n agree on the price p_n^u, their payoffs are

$$\left\{\Pi_n^u[p_n^u, (p_{-n}^u)^*], \Pi_n^d[p_n^u, (p_{-n}^u)^*]\right\}, \tag{31}$$

where the superscript $*$ denotes equilibrium prices, $\Pi_n^u[p_n^u, (p_{-n}^u)^*]$ is determined by equations (26) and (29), and $\Pi_n^d[p_n^u, (p_{-n}^u)^*]$ is determined by equation (30). If they disagree with each other, the export firm can export to another import firm k ($k \neq n$) at equilibrium price $(p_k^u)^*$ with probability $\eta(N)$, and import firm n can import from another export firm at equilibrium price $(p_n^u)^*$ with probability $\delta(M)$, where $\eta'(N) > 0$ and $\delta'(M) > 0$. Thus the disagree point is a pair of payoffs

$$\left\{\eta(N)\Pi_n^u[(p_k^u)^*, (p_n^u)^*, (p_{-k,-n}^u)^*], \delta(M)\Pi_n^d[(p_n^u)^*, (p_{-n}^u)^*]\right\}. \tag{32}$$

[31] c is assumed to be a constant, which implies the symmetry between differentiated varieties.
[32] which involves using the symmetry between differentiated varieties.

The export firm and import firm n maximize the Nash product

$$\max_{p_n^u} \left\{\Pi_n^u[p_n^u, (p_{-n}^u)^*] - \eta(N)\Pi_n^u[(p_k^u)^*, (p_n^u)^*, (p_{-k,-n}^u)^*]\right\} \times \left\{\Pi_n^d[p_n^u, (p_{-n}^u)^*] - \delta(M)\Pi_n^d[(p_n^u)^*, (p_{-n}^u)^*]\right\}. \tag{33}$$

Equilibrium Substituting (26) (29) (30) into (33), and using the equilibrium condition $p_k^u = p_n^u$ and $q_k = q_n$, we can solve for the equilibrium upstream price:

$$p_n^u = \frac{a(2-c)\lambda(M) + b(1+\tau)[2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}{(2-c)\lambda(M) + [2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}, \tag{34}$$

where $\lambda(M) = 1 - \delta(M)$ and $\phi(N) = 1 - \eta(N)$. Obviously $\lambda'(M) = -\delta'(M) < 0$, and $\phi'(N) = -\eta'(N) < 0$. $\lambda(M)$ is the probability that an import firm could not find an export firm, and thus it measures the market power of export firms in the upstream market. $\phi(N)$ is the probability that an export firm could not find an import firm, and thus it measures the market power of import firms in the upstream market.

Next, from (29) we can get the equilibrium import quantity q_n (omitted here), and then from (27) we can get the equilibrium downstream price:

$$p_n^d = \frac{a(2-c)[2+(N-1)c]\lambda(M) + \{a + b(1+\tau)[1+(N-1)c]\}\left[2+(N-2)c\right]\left[\lambda(M)+2\phi(N)\right]}{(2-c)[2+(N-1)c]\lambda(M) + [2+(N-1)c][2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}. \tag{35}$$

Note that the markup of the upstream firm is

$$\begin{aligned} MK_n^u =& \frac{p_n^u}{1+\tau} - b \\ =& \frac{a - b(1+\tau)}{(1+\tau)} \cdot \frac{(2-c)\lambda(M)}{(2-c)\lambda(M) + [2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}, \end{aligned} \tag{36}$$

and the markup of the downstream is

$$\begin{aligned} MK_n^d =& p_n^d - p_n^u \\ =& \frac{a - b(1+\tau)}{2+(N-1)c} \cdot \frac{[2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}{(2-c)\lambda(M) + [2+(N-2)c]\left[\lambda(M)+2\phi(N)\right]}. \end{aligned} \tag{37}$$

The share of the markup of the upstream firm out of the total markups is

$$SMK_n^u = \frac{MK_n^u}{MK_n^u + MK_n^d} = \frac{1}{1 + \frac{(1+\tau)}{(2-c)} \cdot \left[1 - \frac{c}{2+(N-1)c}\right] \cdot \left[1 + \frac{2\phi(N)}{\lambda(M)}\right]} \in [0, 1]. \tag{38}$$

Market Structure and Tariff Pass-through From equation (10) we can calculate the tariff pass-through elasticity

$$\Theta \equiv \frac{\partial p_n^u}{\partial(1+\tau)} \frac{(1+\tau)}{p_n^u} = \frac{1}{1 + \frac{a(2-c)}{b(1+\tau)[2+(N-2)c]\left[1+\frac{2\phi(N)}{\lambda(M)}\right]}} \in [0, 1]. \tag{39}$$

Then we can explore the relationship between tariff pass-through and market structure, more specifically, the market power of export firms and that of import firms.

First, notice that the market power of export firms only exists in the upstream market (in the bargaining over the upstream price) and is captured by $\lambda(M)$. Thus its impact on tariff pass-through is captured by the term $\lambda(M)$ in equation (39). We can show that

$$\frac{\partial \Theta}{\partial \lambda(M)} < 0. \tag{40}$$

This inequality says that tariff pass-through is negatively related to the market power of export firms. The intuition is the following: The higher is the market power of export firms, the higher are the markups they can get through the upstream market bargaining (we can show that $\frac{\partial MK_n^u}{\partial \lambda(M)} > 0$ and $\frac{\partial SMK_n^u}{\partial \lambda(M)} > 0$), the more of the tariff change they will absorb through markup adjustment, and the less of the tariff change they will pass to import firms.[33]

Second, notice that the market power of import firms not only exists in the upstream market (in the bargaining over the upstream price), which is captured by $\phi(N)$, but also exists in the downstream market (in the competition in downstream sales), which is captured the inverse of the number of import firms ($1/N$). Thus its impact on tariff pass-through is captured by the two terms, $\phi(N)$ and N, in equation (39). We can show

[33] One extreme case is: $\delta(M) = 1$ and thus $\lambda(M) = 0$, i.e., export firms do not have any market power in the upstream market. Then we can get $p_n^u = b(1+\tau)$, $MK_n^u = 0$, and $SMK_n^u = 0$ (by (34), (36), and (38), respectively), i.e., their prices are equal to their costs, and they do not have any markups. In this case, export firms have to pass all tariff changes to import firms, that is, $\Theta = 1$ (by (39)).

that

$$\frac{\partial \Theta}{\partial \phi(N)} > 0, \tag{41}$$

$$\frac{\partial \Theta}{\partial (\frac{1}{N})} < 0. \tag{42}$$

These two inequalities indicate that the market power of import firms have two opposite effects on tariff pass-through:

Inequality (41) says that tariff pass-through is positively related to the market power of import firms in the upstream market. The intuition is opposite to what we have discussed for (40): The higher is the market power of import firms in the upstream market, the lower are the markups that export firms can get through the upstream market bargaining (it is easy to see that $\frac{\partial MK_n^u}{\partial \phi(N)} < 0$ and $\frac{\partial SMK_n^u}{\partial \phi(N)} < 0$), the less of the tariff change they will absorb through markup adjustment, and the more of the tariff change they will pass to import firms. [34]

Inequality (42) says that tariff pass-through is negatively related to the market power of import firms in the downstream market. The intuition is as follows: The higher is the market power of import firms in the downstream market, the more of the costs they can transfer to consumers, and thus the higher are the markups that export firms will set in the upstream market bargaining (we can show that $\frac{\partial MK_n^u}{\partial (\frac{1}{N})} > 0$ and $\frac{\partial SMK_n^u}{\partial (\frac{1}{N})} > 0$), the more of the tariff change that export firms will absorb through markup adjustment, and the less of the tariff change they will pass to import firms.

Taking both effects into account, the overall impact of the market power of import firms on tariff pass-through is ambiguous and depends on the comparison of these two effects. If the first effect outweighs the second one, then tariff pass-through is positively related to the market power of import firms; otherwise, they are negatively related to each other. Hence the overall impact of the market power of import firms on tariff pass-through should be investigated empirically.

[34] One extreme case is: $\eta(N) = 1$ and thus $\phi(N) = 0$, i.e., import firms do not have any market power in the upstream market. In this case the markups of export firms (MK_n^u and SMK_n^u) achieve the maximum (by (36) and (38)), and the tariff pass-through elasticity (Θ) achieves the minimum (by (39)). Note that the maximum of SMK_n^u is less than 1, and thus the minimum of Θ is greater than 0. This is because import firms can always get a certain amount of markups by utilizing their market power in the downstream market.

There are two things worth pointing out here. First, as we can see from the analysis above, both the market power of export firms and that of import firms impact tariff pass-through via markups of export firms: the higher the markups of export firms, the higher is tariff absorption and the lower is tariff pass-through. Second, some people may wonder how the market power of domestic import firms impacts the welfare of the home country and that of the export country, more specifically, whether the failure to prevent market power domestically could be seen as a beggar-thy-neighbor trade policy. As we can see from the analysis, the impact of the market power of domestic import firms on initial markups of foreign export firms and its impact on the magnitude of tariff pass-through are both ambiguous, and need to be investigated empirically.

3. Empirical Specification

The model predicts that tariff pass-through is negatively related to the market power of export firms, but its dependence on the market power of import firms is ambiguous and hence need to be investigated empirically. We use the following benchmark specification to test these predictions:

$$\begin{aligned}\Delta lnP_{ict} =& \alpha + \beta\Delta ln(1+\tau_{it}) \\ &+ \lambda[\Delta ln(1+\tau_{it}) \times DH^x_{i(t-1)}] + \phi[\Delta ln(1+\tau_{it}) \times DH^m_{i(t-1)}] \\ &+ \rho DH^x_{i(t-1)} + \sigma DH^m_{i(t-1)} \\ &+ \gamma_1\Delta lnER_{c(t-1)} + \gamma_2\Delta lnCPI_{ct} + \gamma_3\Delta lnRGDP_t \\ &+ FE + \varepsilon_{ict}.\end{aligned} \tag{43}$$

In this specification, ΔlnP_{ict} is the change of log import price (tariff-inclusive) of the home country of product i imported from country c from period $t-1$ to period t, and $\Delta ln(1+\tau_{it})$ is the change of log gross (ad-valorem) tariff rate imposed by the domestic country on the product. $H^x_{i(t-1)}$ is the Herfindahl concentration index of foreign export firms (from all foreign countries) that export product i to the home country in the base period $t-1$, which is used to measure the market power of export firms; $DH^x_{i(t-1)}$ is a dummy variable, which is set to equal 1 if the the Herfindahl concentration index of foreign export firms in product i is higher than the average index of foreign export firms across different products. Similarly, $H^m_{i(t-1)}$ is the Herfindahl concentration index of domestic import firms that import product i (from any foreign country) in the base period $t-1$, which is used to measure the market power of import firms; $DH^m_{i(t-1)}$ is a dummy variable, which is set to equal 1 if the the Herfindahl concentration index of domestic import firms in product i is higher than the average index of domestic import firms across different products. $\Delta lnER_{c(t-1)}$ is the change of log exchange rates between the export country c and the home country one period ahead of the tariff change,[35] $\Delta lnCPI_{ct}$ is the change of log consumer price index of the export country c, and $\Delta lnRGDP_t$ is the change of log real GDP of the home country. FE denotes various fixed effects.

In this specification, the coefficient for the direct term of tariff change, β, measures the tariff pass-through elasticity when both the market power of export firms and that of import firms are low. According to (39), it should be positive, with normal range [0, 1]. The coefficient for the interaction term between the tariff change and the export Herfindahl index dummy, λ, measures the impact of increasing the market power of export firms on tariff pass-through; Similarly, coefficient ϕ measures the impact of increasing the market power of import firms on tariff pass-through. The theoretical model predicts λ to be negative but ϕ ambiguous — this will be the focus of our empirical test. The two direct terms of the Herfindahl concentration indexes are added to the specification to capture their direct impacts on import price changes. The model does not have an unambiguous prediction about the signs of their coefficients, ρ and σ.

The coefficient for the exchange rate changes, γ_1, measures exchange rate pass-through elasticity. When import prices are denoted in the domestic currency, and exchange rates are denoted as units of foreign currencies per unit of the domestic currency, γ_1 should be negative, since the appreciation of the domestic currency should lead to a reduction of import prices denoted in the domestic currency. The CPI changes of export countries measure the inflation rates and production cost changes in export countries. Its

[35]We use the exchange rate change one period ahead of the tariff change since exchange rate pass-through typically has a lag effect, as shown in the exchange rate pass-through literature.

coefficient γ_2 should be positive, since the increase in production cost should lead to an increase in the import price[36]. The changes of the real GDP of the home country measures the demand change of the home country. Its coefficient γ_3 should be positive, since the increase in the market demand should lead to an increase in the import price[37].

4. Data

The main dataset that we use in the empirical analysis is the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which was assembled by Bernard, Jensen and Schott (2008). The database links all individual U.S. import and export transactions to the respective U.S. firms; in the case of U.S. imports, the database also contains the information about the foreign export firms. The dataset comes from two sources: one is the foreign trade data (FTD) assembled by the U.S. Census Bureau (for exports) and U.S. customs(for imports), which contains all U.S. international trade transactions between 1992 and 2005 inclusive; the other one is the Longitudinal Business Database (LBD) of the U.S. Census Bureau, which records annual employment and survival information for most U.S. establishments. We use the U.S. import data in the LFTTD database in the period 1995-1999, the applied period of Uruguay Round, to investigate how U.S. tariff reduction caused by Uruguay Round pass through to U.S. import prices. For each import transaction, the database records its product category (at HS10 level), quantity, (tariff-exclusive) value, duty paid, exporting country, foreign export firm, U.S. import firm, year and month in which the transaction occurs, whether the transaction is an arm's length transaction or takes place between related parties[38], etc.

Import price changes are computed from import values and quantities. Before constructing import price changes, We clear the data in the following way. (1) Among all transactions, we first drop those with missing values in value, quantity, duty, product category, export country, export firm, import firm, or time. (2) Since measurement error

[36]It is also easy to prove, from equation (34), that $\partial p_n^u / \partial b > 0$.

[37]It is also easy to prove, from equation (34), that $\partial p_n^u / \partial a > 0$, where a is the demand shifter (according to equation (27)).

[38]Related-party transactions refer to trade between U.S. companies and their foreign subsidiaries and trade between U.S. subsidiaries of foreign companies and their affiliates abroad.

in values or quantities causes measurement error for the constructed import prices and leads to biased estimation, we 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-export firm-export country-year" cell. (3) We also remove related party transactions (around 30 percent of the total), since the price behavior for related party transactions is quite different from normal arm's length transactions. For the rest of transactions, we construct firm-level prices (unit values) as $P^*_{imcnt} = V_{imcnt}/Q_{imcnt}$, where V_{imcnt} and Q_{imcnt} are the total value and quantity of product i (HS10) exported by foreign firm m from country c to domestic firm n in year t. Since import values are tariff-exclusive, the constructed import prices are also tariff-exclusive. We adjust these prices by the tariff rates (which will be discussed below) to get the tariff-inclusive import prices $P_{imcnt} = P^*_{imcnt}(1 + \tau_{it})$. Among all "product-export firm-export country-import firm-year" cells that we constructed import prices, we keep those surviving in two consecutive years. For these surviving cells we get the firm-level changes of log prices $\Delta lnP_{imcnt} = lnP_{imcnt} - lnP_{imcn(t-1)}$. Then we average these firm-level price changes (across different export firms and different import firms) to get the product-level price changes, $\Delta lnP_{ict} = \sum_{m=1}^{M}\sum_{n=1}^{N} \Delta lnP_{imcnt}/N_{mn}$, where N_{mn} is the number of "export firm-import firm" pairs within the same "product-export country-year" cell.

Tariff rates are obtained by combining the LFTTD data and the U.S. Tariff Schedule. The LFTTD data contain the duties paid for each transaction. Theoretically speaking, we can compute the tariff rate for each transaction by combining the duties and the values of the transaction (when ad valorem tariff applies) or quantities of transactions (when specific tariff applies) or both (when both tariffs apply). However, the LFTTD data do not indicate whether an ad valorem or specific tariff applies to each transaction. Thus, we link the data to the US Tariff Schedule, which contains tariff rates at 8-digit HS level as well as whether the rates are ad valorem or specific rates. We restrict the analysis to transactions for which (1) only ad valorem tariffs apply and (2) the computed ad valorem tariff rates (duties/values) and the imputed ad valorem tariff rates (from U.S. Tariff Schedule) are consistent with each other. The reasons for restricting the analysis to transactions with ad valorem tariffs are the following. First, ad valorem tariffs and specific tariffs are not equivalent, especially when we estimate the tariff pass-through elasticity, i.e., the percent change of the import price in response to a percent change in the tariff rate. Second, If we calculate the ad valorem equivalence of a specific tariff using the duty and the import value, and use it as a regressor, then it will cause an endogeneity problem, since the import value is affected by the import price, which is the dependent variable in regressions.

As indicated in section 3, we will use Herfindahl concentration index of export firms and that of import firms to measure their market power. Since the LFTTD data contain the information for product category, value, export firm, import firm, and transaction time for each import transaction, these two index can be constructed easily:

$$H_{it}^{x} = \sum_{m=1}^{M} \frac{(V_{mit})^2}{(\sum_{m=1}^{M} V_{mit})^2}$$

$$H_{it}^{m} = \sum_{n=1}^{N} \frac{(V_{nit})^2}{(\sum_{n=1}^{N} V_{nit})^2}$$

where V_{mit} and V_{nit} are the export value of the export firm m and the import value of the import firm n, respectively, in product i in period t. [39]

The data for exchange rates and GDP come from the Penn World Table, and the data for CPI come from International Financial Statistics (IFS) of the International Monetary Fund.

Table 1 contains some summary statistics for the full sample and the main variables used in the benchmark regression.[40] The upper panel of the table shows that the sample contains 91 2-digit level HS product categories, and thus it is very representative. There

[39]When we construct the two Herfindahl concentration indexes, we have excluded export and import firms that conduct related-party transactions, as what we did for constructing the price changes. However, when firms that conduct arm's length transactions make pricing decisions, they may still need to consider the competition from firms that conduct related-party transactions. Thus an alternative way of constructing the two Herfindahl concentration indexes is to include export and import firms that conduct related-party transactions.

[40]Note that the sample size is constrained by the following operations: (i) As mentioned in the beginning of this subsection, many import transactions were dropped when we constructed the export price and their changes. (ii) When we combined the export price changes with tariff changes, we also dropped transactions with specific tariffs and those for which the computed ad valorem tariff rates (duties/values) are not consistent with the imputed ad valorem tariff rates (from U.S. Tariff Schedule).

are a total of over 4,700 8-digit HS products and over 7,500 10-digit HS products within these product categories. The sample contains 108 countries that export to the U.S., including all the main trade partners of the U.S. The imports from these countries occurred between over 56,000 exporting firms from these countries and over 21,000 importing firms in the U.S. The lower panel of the table shows that there are a total of over 96,000 observations ("product-export country-year" cells) in the sample. The simple average log price change of all observations in the sample is −0.016, which means that on average the tariff-inclusive prices decrease by 1.6 percent. The simple average tariff change is −0.002, which means that on average the tariff rates reduce by 0.2 percent. The average exchange rate (units of foreign currencies per unit of the U.S. dollar) change, the average inflation rate in the exporting countries, and the average GDP growth rate in the U.S. are 6 percent, 5 percent, and 5 percent, respectively. The average Herfindahl concentration indexes for exporting firms and that for import firms are both around 0.18, which is not very high and implies that the competition between exporting firms and that between importing firms are pretty severe on average.

Note that the LFTTD data used in this paper contain all types of import products of the U.S. We will run the benchmark regression not only for the full sample, but also for different subgroups of products: commodity goods v.s. differentiated goods, and intermediate goods v.s. consumption goods.[41]

5. Empirical Results

This section presents the regression results.

Table 2 contains the regression results for the benchmark full sample with all products pooled together. We run the benchmark regression in three steps, with results in the three columns: (1) only include the tariff changes as the regressor; (2) add other controls (exchange rate changes, CPI changes, and GDP changes) to the regressors; (3)

[41] In the benchmark regression we use concentration indexes as measures of market power to explore how market structure impacts tariff pass-through. Alternatively, we can also directly divide all industries into different groups in terms of the number of export firms and import firms in each industry, which reflects the degree of competition within the industry, and then explore how tariff pass-through varies across these different groups of industries.

add the Herfindahl concentration indexes for export firms and import firms and their interaction with tariff changes. In each regression, we include a product and a year fixed effect to capture the impacts of any unobserved product-specific and time-specific shocks on import price changes[42]. We do not include a country fixed effect, since there are already two regressors, exchange rate changes and CPI changes, that capture the impacts of country-specific shocks on price changes.

In column (1), the estimate for the coefficient, which measures tariff pass-through elasticity, is negative (−0.28) and significant. A negative tariff pass-through elasticity implies that when foreign export firms face a tariff reduction, they raise their tariff-exclusive prices by a very large magnitude, so that the tariff-inclusive prices actually increase instead of decreasing. This is known as the "Metzler Paradox". A possible explanation is that export firms not only increase their markups but also upgrade their product quality in response to a tariff reduction, and hence their tariff-exclusive prices increase by a very large magnitude[43].

In column (2), after we add the other three control variables, the sign of the coefficient for tariff changes does not change, which again confirms the existence of the "Metzler Paradox". The coefficient for exchange rate changes, which measures the exchange rate pass-through elasticity, is negative (−0.02). This is qualitatively consistent with the expectation that a U.S. dollar appreciation will lead to a reduction of U.S. import prices. However, the coefficient is not significant[44]. The coefficients for the CPI changes of the export country and the GDP changes of the U.S. (import country) are both positive and significant (0.004 and 3.27, respectively). This is consistent with the model predictions that an increase of the production cost and an increase of the market demand both lead

[42]Note that since we use the first order difference specification, we have actually removed the impacts of any time-invariant fixed effects (product, country, and product-country) on price levels. The fixed effects in current regressions capture their impacts on price changes instead of price levels.

[43]See Ludema and Yu (2011) for an theoretical model and empirical studies on this at the firm-level.

[44]As you will see, even though we get significant tariff pass-through elasticities in almost all regressions throughout the paper, we do not get significant exchange rate pass-through elasticity in any regression. Two possible explanations are: (1) As we indicated earlier, exchange rate pass-through has a lag effect, but the length of the lag effect depends on the nature of contracts of trade transactions, which is very complicated in reality, and thus our specification of one-period lag effect may be inaccurate. (2) In many cases firms regard exchange rate changes as temporary changes, but tariff changes as permanent changes. Thus firms' response to exchange rate changes is less prominent than their response to tariff changes.

to an increase in the U.S. import prices.

In column (3), after we add the Herfindahl concentration indexes for export firms and import firms, as well as their interactions with tariff changes, the sign of the coefficient for tariff changes turns to positive (0.30). Note that now the coefficient measures the tariff pass-through elasticity when both the market power of export firms and that of import firms are low. In this case, the markups of export firms are relatively low; when they face a tariff change, they are only able to absorb a small portion of the tariff change, and hence need to pass a large portion of the tariff change to import firms. This explains why we get a positive tariff pass-through elasticity for this case. The coefficients for exchange rate changes, CPI changes of export countries, and GDP changes of the import country have the same signs as before, which is consistent with model predictions.

More importantly, the coefficient for the interaction term between tariff changes and the Herfindahl concentration index for export firms is negative (-0.32) and significant, which implies that tariff pass-through is negatively related to the market power of export firms. This is perfectly consistent with the model prediction. Meanwhile, the coefficient for the interaction term between tariff changes and the Herfindahl concentration index for import firms is also negative (-3.56) but not significant. This is also consistent with the model prediction that tariff pass-through has an ambiguous relationship with the market power of import firms. According to the model, the negative estimate implies that the impact of the market power of import firms through both downstream and upstream markets outweighs its impact only through the upstream market, and its overall impact on tariff pass-through is insignificant. The coefficients for the two direct terms of the Herfindahl concentration indexes are also insignificant, and the model does not have a clear prediction for these two coefficients.

The estimation results presented above show that the predictions of the model, especially those on the relationship between tariff pass-through and market structure, are supported by empirical evidence.

Next, we do some robustness check by running the benchmark regression for four subsamples: commodity goods v.s. differentiated goods, and intermediate goods v.s. final goods.

Table 3 contains the regression results for commodity goods and differentiated goods. Rauch (1999) classifies products into commodities and differentiated goods: goods traded on organized exchanges or with reference prices are classified as commodities, and others are classified as differentiated goods. For each group, we run the benchmark regression in three steps as in the full sample. An obvious finding is that, for both groups of products, the coefficients for all estimates in all the three regressions almost have the same signs as in the full sample case; however, none of these coefficients is significant for the group of commodity goods, but the significance of estimates for the group of differentiated goods is similar to the full sample case. This finding indicates that the patterns that we found for the full sample case are mainly driven by the group of differentiated goods instead of commodity goods. A possible explanation is the following. Both the incompleteness of tariff pass-through and its dependence on market structure are mainly due to markup adjustment, but markups mainly exist in differentiated goods but not commodity goods; hence both the incompleteness of tariff pass-through and its dependence on market structure are only significant for differentiated goods but not commodity goods[45].

Table 4 contains the regression results for intermediated goods and final goods. Here we find that for both groups of products, the signs and the significance of all estimates in all the three specifications are very similar to what we find in the full sample. This is consistent with the model settings that apply to both intermediate goods and consumption goods.

6. Conclusions and Forward Research

This paper studies how tariff pass-through depends on market structure, i.e., the competition between foreign export firms and that between domestic import firms. If foreign export firms have high market power and hence high markups in their export prices, they

[45]This argument also holds if quality adjustment is another driving force for incomplete tariff pass-through, since quality adjustment mainly occurs for differentiated goods (with high scope for quality differentiation) but not for commodity goods (with low scope for quality differentiation). See Ludema and Yu (2011) for a more detailed analysis.

are able to absorb more of the tariff change by adjusting their markups, and thus pass less of the tariff change to domestic import firms. If domestic import firms have high market power, they are able to force foreign export firms to lower markups and export prices on the one hand; On the other hand, they may also be able to accept high markups and export prices set by foreign export firms, since they have a high ability to transfer the burden to domestic consumers. The net impact on the actual markups and export prices of foreign export firms, and hence the impact on their ability to adjust their markups in response to a tariff change, depends on the comparison of these two opposite effects. Thus, the relationship between the market power of import firms and tariff pass-through is ambiguous. The paper uses the U.S. transaction-level import data from 1995 to 1999, the applied period of Uruguay Round, to test these predictions. The estimation results show that these predictions are supported by the data.

In this paper, we assume that all export firms in an industry are homogeneous in the sense that they have the same marginal cost of production, and that all import firms in the industry are also homogeneous in the sense that they have the same one-to-one input-output production technology. Due to this assumption, we are able to use the number of export firms and that of import firms in the theoretical section, and use the Herfindahl concentration index of export firms and that of import firms in the empirical section, to measure their market power. Because of this, what we have studied in this paper is how an industry level characteristic (market structure) impacts tariff pass-through. However, firms in the real world are actually heterogeneous in terms of their productivity. This has been indicated in the heterogeneous firm models in international trade, such as Melitz (2003), as well as relevant empirical studies, such as Bernard and Jensen (1995). A natural question is: how does firm heterogeneity in productivity impact tariff pass-through? We would answer this question in another paper, Ludema and Yu (2011).

References

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

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., Jensen, J. B., and Schott, P. (2008), "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trades Goods", forthcoming in Dunne, T., Jensen, J. B., and Roberts, M. J., eds *Producer Dynamics: New Evidence from Micro Data*, University of Chicago Press.

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

Durham, Y. (2000), "An Experimental Examination of Double Marginalization and Vertical Relationships." *Journal of Economic Behavior and Organization*, 42: 207-229.

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.

Francois, J., and I. Wooton (2005), "Market Structure in Services and Market Access in Goods." *CEPR Discussion Papers*: 5135, 2005.

Horn, H., and A. Wolinsky (1988), "Bilateral Monopolies and Incentives for Merger", *Rand Journal of Economics*, Vol. 19, No. 3, Autumn 1988, pp. 408-419.

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.

Ludema, R., and Z. Yu (2011), "Tariff Pass-through, Firm Heterogeneity and Product Quality",*Working Paper*, 2011.

Mallick, S., and H. Marques (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).

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

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

Rezitis, A. N., and A. B. Brown (1999), "Pass-through of Exchange Rates and Tariffs in Greek-US Tobacco Trade." *Agricultural Economics*, 21:269-277.

Tables

Table 1. Summary Statistics for the Full Sample

No. of HS2	91		
No. of HS8	4,745		
No. of HS10	7,542		
No. of Export Countries	108		
No. of Export Firms	56,398		
No. of Import Firms	21,648		
Variables	No. of Obs.	Mean	Std.Dev.
ΔlnP_{ict}	96,725	-0.016	0.643
$\Delta \tau_{it}$	96,725	-0.002	0.003
$\Delta lnER_{c(t-1)}$	96,725	0.062	0.159
$\Delta lnCPI_{ct}$	96,725	0.052	0.181
$\Delta lnRGDP_{t}$	96,725	0.046	0.003
$DH^{x}_{i(t-1)}$	96,725	0.180	0.384
$DH^{m}_{i(t-1)}$	96,725	0.184	0.388

Table 2. Tariff Pass-through and Market Structure: All Products Together

Dependent Variable: ΔlnP_{ict}

Regressions	(1)	(2)	(3)
$\Delta ln(1+\tau_{it})$	−0.28*	−0.13*	0.30*
	(0.16)	(0.07)	(0.17)
$\Delta lnER_{c(t-1)}$		−0.02	−0.02
		(0.02)	(0.02)
$\Delta lnCPI_{ct}$		0.004*	0.004*
		(0.002)	(0.002)
$\Delta lnRGDP_{t}$		3.27***	3.29***
		(0.69)	(0.69)
$\Delta ln(1+\tau_{it}) \times DH^{x}_{i(t-1)}$			−0.32*
			(0.17)
$\Delta ln(1+\tau_{it}) \times DH^{m}_{i(t-1)}$			−3.56
			(3.39)
$DH^{x}_{i(t-1)}$			−0.02
			(0.02)
$DH^{m}_{i(t-1)}$			0.03
			(0.02)
Fixed Effects	product +year	product +year	product +year
No. of Obs.	96,725	96,725	96,725
R^2	0.10	0.10	0.10

Table 3. Tariff Pass-through and Market Structure: Commodities v.s. Differentiated Goods

Dependent Variable: ΔlnP_{ict}

Type of Products	Commodity Goods			Differentiated Goods		
Regressions	(1)	(2)	(3)	(1)	(2)	(3)
$\Delta ln(1+\tau_{it})$	-0.18	1.16	2.48	-0.16*	-0.04*	0.32*
	(9.32)	(9.34)	(9.89)	(0.09)	(0.02)	(2.00)
$\Delta lnER_{c(t-1)}$		-0.07	-0.07		-0.02	-0.02
		(0.08)	(0.08)		(0.02)	(0.02)
$\Delta lnCPI_{ct}$		0.07	0.07		0.002	0.002
		(0.12)	(0.12)		(0.02)	(0.02)
$\Delta lnRGDP_t$		4.02	4.09		3.15***	3.17***
		(2.33)	(2.33)		(0.73)	(0.73)
$\Delta ln(1+\tau_{it}) \times DH^x_{i(t-1)}$			-0.88			-0.45*
			(9.40)			(0.23)
$\Delta ln(1+\tau_{it}) \times DH^m_{i(t-1)}$			-4.47			-3.30
			(9.02)			(3.67)
$DH^x_{i(t-1)}$			-0.02			-0.02
			(0.03)			(0.02)
$DH^m_{i(t-1)}$			-0.004			0.03*
			(0.03)			(0.02)
Fixed Effects	product +year	product +year	product +year	product +year	product +year	product +year
No. of Obs.	9,278	9,278	9,278	87,447	87,447	87,447
R^2	0.13	0.13	0.13	0.09	0.09	0.09

Table 4. Tariff Pass-through and Market Structure:
Intermediate v.s. Consumption Goods

Dependent Variable: ΔlnP_{ict}

Type of Products		Intermedia-te Goods			Consump-tion Goods	
Regressions	(1)	(2)	(3)	(1)	(2)	(3)
$\Delta ln(1+\tau_{it})$	−0.62*	−0.50*	0.01*	−0.06*	0.04*	0.44*
	(0.32)	(0.2)	(0.006)	(0.03)	(0.02)	(0.23)
$\Delta lnER_{c(t-1)}$		−0.04	−0.04		−0.01	−0.01
		(0.03)	(0.03)		(0.02)	(0.02)
$\Delta lnCPI_{ct}$		0.01	0.01		0.01	0.01
		(0.04)	(0.04)		(0.02)	(0.02)
$\Delta lnRGDP_t$		3.93***	3.96***		2.01***	2.03***
		(1.07)	(1.07)		(0.81)	(0.81)
$\Delta ln(1+\tau_{it}) \times DH^x_{i(t-1)}$			−1.03*			−1.89*
			(0.52)			(0.95)
$\Delta ln(1+\tau_{it}) \times DH^m_{i(t-1)}$			−1.63			−6.91
			(4.84)			(4.34)
$DH^x_{i(t-1)}$			−0.02			−0.004
			(0.02)			(0.02)
$DH^m_{i(t-1)}$			0.03			0.01
			(0.02)			(0.02
Fixed Effects	product +year	product +year	product +year	product +year	product +year	product +year
No. of Obs.	55,225	55,225	55,225	40,607	40,607	40,607
R^2	0.10	0.10	0.10	0.08	0.08	0.08

Essay 3. Tariff Spillover Effect: Theory and Empirical Evidence[§]

Zhi Yu[†]

Georgetown University
Department of Economics

July 2011

Abstract: This paper studies how tariff changes of a country impact trade prices between its trade partners. I use a simple model to show that, when a foreign country reduces its tariffs (either MFN or non-MFN tariffs), domestic exporting firms not only raise their tariff-exclusive prices toward the country that reduces its tariffs, which is known as "incompleteness of tariff pass-through" in the literature, but also raise their prices toward third countries, which I refer to as "tariff spillover effect". This "tariff spillover effect" on export prices toward third countries is comparable to "trade deflection" on export quantities toward third countries, which was studied by Bown and Crowley (2007). The existence of the effect depends on the assumption of increasing marginal cost: tariff reduction of a foreign country leads to an increase of export quantities and total output of domestic exporting firms, which leads to an increase of their marginal costs and export prices, regardless of their export destinations. Using the newly available transaction level data on US exports during the period 1995-1999, the applied period of Uruguay Round, I find empirical evidence for this prediction.

Key Words: Tariff Spillover Effect
JEL Numbers: F1, D4, L1

[§] I am very grateful to Rodney Ludema for his invaluable guidance and continuous support for this paper. I also thank Anna Maria Mayda, J. Bradford Jensen, and Meredith Crowley for helpful comments and suggestions. Support for this research at the Census Bureau RDC from NSF (ITR-0427889) is gratefully acknowledged. The research in this paper was conducted while the author was a Special Sworn Status researcher at the U.S. Census Bureau, Center for Economic Studies. Results and conclusions expressed are those of the author and do not necessarily reflect the views of the Census Bureau. The results presented in this paper have been screened to ensure that no confidential data are revealed.

[†] Georgetown University, Department of Economics, 37th and O Streets, Washington, DC 20057, U.S.A. E-mail: zy24@georgetown.edu.

1. Introduction

This paper studies how tariff changes of a country impact trade prices between its trade partners. I use a simple model to show that, when a foreign country reduces its tariffs (either MFN or non-MFN tariffs), domestic exporting firms will raise their prices toward third countries, which I refer to as "tariff spillover effect". The existence of the effect depends on the assumption of increasing marginal cost: tariff reduction of a foreign country leads to an increase of export quantities and the total output of domestic exporting firms, which leads to an increase of their marginal costs and export prices to all destination countries. Using the transaction level data on US exports during the period 1995-1999, the applied period of Uruguay Round, I find empirical evidence for this prediction.

This paper extends the literature in two areas. The first literature related to the paper is that on "incompleteness of tariff pass-through". The key claim in this literature is that, when a foreign country reduces its tariffs, domestic exporting firms will raise their tariff-exclusive prices toward the liberalizing country, and thus the tariff-inclusive consumer prices in the liberalizing country only reduce by a magnitude smaller than the tariff reduction. In other words, domestic exporting firms absorb part of the tariff reduction, and only pass the rest of the reduction to consumers in the liberalizing country. Tariff reduction worsens terms of trade for the liberalizing country and improves the terms of trade of its trading partners. This terms-of-trade effect is the basis for the optimal tariff argument[46], from Edgeworth (1894) to Broda, Limão and Weinstein (2008), Bagwell and Staiger (2009), and Ludema and Mayda (2010). Empirical evidence of incompleteness of tariff pass-through could be found in Kreinin (1961), Feenstra (1989), Mallick and Marques (2007), and Ludema and Yu (2011a, 2011b), among others.

This paper extends the studies on incomplete tariff pass-through by changing the focus of the studies. Instead of focusing on how domestic exporting firms change their prices toward the liberalizing country, this paper focuses on how they change their prices toward third countries in response to the tariff reduction of the liberalizing country. I

[46] The argument says that, 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 from a tariff increase.

found, both theoretically and empirically, that when a foreign country reduces its tariffs, domestic exporting firms not only raise their tariff-exclusive prices toward the liberalizing country, but also raise their prices toward third countries. I refer to the latter effect as "tariff spillover effect".

The second literature related to this paper is the side effect of trade policies on trade flows. The studies on this side effect could be traced back to Viner (1950), who showed that discriminatory trade policies associated with preferential trade agreements (PTAs) not only have "trade creation effect", replacing the domestic production with imports from members of PTAs, but also have "trade diversion effect", replacing imports from non-members of PTAs with imports from members of PTAs. This "trade diversion effect" is a kind of side effect. As an example, Romalis (2002) explores how the North America Free Trade Agreement (NAFTA) and the earlier Canada-US Free Trade Agreement (CUSFTA) leads to a U.S. import diversion from other exporting countries to Canada and Mexico. Some other studies (Bagwell and Staiger, 1997, 1999, 2004; Levy, 1997; Ethier, 2004; among others) investigate how preferential policy exceptions in multilateral trade agreements impact trade flows. All these studies focus on *import source diversion.* Bown and Crowley (2007) explores another type of side effect from the perspective of *export diversion.* They showed, both theoretically and empirically, how an antidumping/safeguard tariff of a country (U.S.) leads to a diversion of the export flows of another country (Japan) to third countries. They refer to this type of side effect as "trade deflection".

This paper extends the literature on the side effect of trade policies from trade flows to trade prices. The paper is most related to the studies of Bown and Crowley (2007) on "trade deflection". In terms of the main objective, both papers look at how the trade policy of a country impacts the export of another country to third countries. Moreover, both papers consider two types of trade policies: discriminatory policies (antidumping or non-MFN tariffs), which target specific countries, and non-discriminatory policies (safeguards or MFN tariffs), which are applied equally to all countries. The key difference is: Bown and Crowley (2007) focus on the impact on export quantities, while my paper focuses on the impact on export prices. Another difference is: Bown and Crowley (2007) look at how U.S. antidumping/safeguard tariffs impact Japanese export (quantities) to third countries, while my paper looks at how general tariff changes (increases or reductions) of a large set of foreign countries impact the U.S. export (prices) to third countries.

In terms of the theoretical models, both papers are built on a common assumption, increasing marginal cost of production. The assumption is essential for the existence of "trade deflection": since firms equate the net marginal revenue of production for each market in equilibrium, anything that affects the cost of selling in one market will cause firms to reallocate their sales across markets. The assumption is also critical for the existence of "tariff spillover effect": with increasing marginal cost, tariff reduction of a foreign country leads to an increase of the production quantity of the domestic exporting firms, and hence an increase of their marginal costs and export prices, regardless of their export destinations. The difference between the models in the two papers is: Bown and Crowley (2007) use a Cournot model with quantity competition since they look at the side effect of trade policies on trade flows, while I use a Betrand model with price competition since I look at the side effect of trade policies on trade prices.[47]

The paper is organized as follows. Section 2 presents the theoretical model. Section 3 contains the empirical specification. Section 4 describes the dataset. Section 5 includes the preliminary estimation results. Conclusions are included in section 6.

2. The Model

2.1 The Setup

Assume that there are three countries indexed i, j or $k \in \{a, b, c\}$. There is one representative firm in each country, also indexed i or j or k, each produces a differentiated product. Markets are segmented. Each of the three firms sells in all the three markets. The three firms that sell in the same market conduct Bertrand competition in prices. The tariff-inclusive price of the product that firm i sells in country j is $p_{ij} = p^*_{ij} + \tau_{ij}$, where p^*_{ij} is the tariff-exclusive price and τ_{ij} is the tariff that country j imposed on the import

[47]This difference is not critical. I can use either model in both cases and get the same conclusions. It is just a natural choice to use a Cournot model to explore quantity reactions and use a Bertrand Model to investigate price responses.

from country i. $p_{ii} = p^*_{ii}$ is the price of the product that firm i sells in its own market, which is not subject to any tariff, i.e., $\tau_{ii} = 0$.

Demand of the product that firm i sells in country j is given by the linear function

$$q_{ij} = A - Bp_{ij} + Dp_{kj} + Dp_{jj}, \tag{44}$$

where $A > 0$, $B > 0$, and $D > 0$ are constant. B measures the own price effect, and D measures the cross price effect of the other two products sold in the same market (country j). $D > 0$ implies that products produced by different firms are strategic substitutes. Assume $B > 2D$, i.e., the own price effect is higher than the sum of the two cross price effects[48].

The total output of firm i is $Q_i = \sum_j q_{ij} = q_{ii} + q_{ik} + q_{ij}$. Production technology in each country is the same and exhibits increasing marginal cost. The total cost function is $c(Q_i)$, where $c'(Q_i) > 0$ and $c''(Q_i) > 0$. The objective of firm i is to choose a level of price for each market, p_{ii}, p_{ik}, and p_{ij}, in order to maximize its profits, i.e.,

$$Max \quad \pi_i = \sum_j (p_{ij} - \tau_{ij})q_{ij} - c(Q_i). \tag{45}$$

The firm's first order condition is given by

$$\frac{\partial \pi_i}{\partial_{p_{ij}}} = q_{ij} - B[p_{ij} - \tau_{ij} - c'(Q_i)] = 0. \tag{46}$$

Solving the first order conditions for each $j \in \{a, b, c\}$ yields firm i's best responses to the price decisions of the other two firms. A best response function specifies a price for each market, given the prices of the firm's two rivals that sell in the same market. Solving the nine best response functions simultaneously yields the Bertrand Nash equilibrium prices set by each firm in each market.

Next I explore how a tariff change of one of the three countries impacts the price of each firm charges for each market. I consider two cases. In the first case, the tariff is

[48] This assumption implies that if p_{ij}, p_{kj}, and p_{jj} increase by the same magnitude, then q_{ij}, q_{kj}, and q_{jj} will decrease, which makes perfect sense.

a discriminatory tariff against a specific country; it could be an antidumping tariff as in Bown and Crowley (2007), or any other non-MFN tariff. In the second case, the tariff is a non-discriminatory tariff applied equally to all countries; it could be a safeguard tariff as in Bown and Crowley (2007), or any other MFN tariff.

2.2 Comparative Statics for a non-MFN tariff

Without loss of generality, suppose that country a reduces its tariff against country b, τ_{ba}, while all the other bilateral tariffs are unchanged.

Proposition 1. *For the three country Bertrand Model in which good are differentiated and are strategic substitutes and firms face increasing marginal cost in production, a unilateral tariff reduction by country a against country b causes*

- *incomplete tariff pass-through, a decrease in country b's tariff-inclusive export price in country a* ($\frac{dp_{ba}}{d\tau_{ba}} > 0$)*, but an increase in the tariff-exclusive price* ($\frac{dp^*_{ba}}{d\tau_{ba}} < 0$)*,*
- *tariff spillover, an increase in country b's export price in country c* ($\frac{dp_{bc}}{d\tau_{ba}} < 0$)*.*

Proof: Totally differentiating the nine first order conditions given by (46), dividing through by $d\tau_{ba}$, applying Cramer's rule, and using the condition $B > 2D$ yields the signs of the following comparative static effects for a change in τ_{ba}: (1) for goods sold in country a, $\frac{dp_{ba}}{d\tau_{ba}} > 0$, $\frac{dp_{aa}}{d\tau_{ba}} > 0$, $\frac{dp_{ca}}{d\tau_{ba}} > 0$; (2) for goods produced in country b, $\frac{dp^*_{ba}}{d\tau_{ba}} < 0$, $\frac{dp_{bb}}{d\tau_{ba}} < 0$, $\frac{dp_{bc}}{d\tau_{ba}} < 0$. QED.

The intuition of these results is pretty straightforward. On the one hand, a unilateral tariff reduction by country a against country b (τ_{ba}) reduces the tariff-inclusive price of the goods that country b sells in country a (p_{ba}), and further pulls down the prices of its two rivals in the same market (p_{aa}, p_{ca}) due to the competition effect. On the other hand, the reduced tariff-inclusive price that country b charges in country a leads to an increase of country b's exports to country a, and in turn an increase of firm b's total output; this will pull up its marginal cost of production, and in turn its tariff-exclusive price in country a (p^*_{ba}) and its prices in the other two markets (p_{bb}, p_{bc}). Thus, the assumption of increasing marginal cost plays a critical role in the existence of the tariff spillover effect, as it does for trade deflection in Bown and Crowley (2007).[49]

[49]Here the tariff spillover effect is derived from the assumption of increasing marginal cost, along with

2.3 Comparative Statics for a MFN tariff

Suppose now all the three countries impose MFN tariffs, that is, $\tau_{ba} = \tau_{ca} \equiv \tau_a$, $\tau_{ab} = \tau_{cb} \equiv \tau_b$, and $\tau_{ac} = \tau_{bc} \equiv \tau_c$.[50] Without loss of generality, suppose that country a reduces its tariff τ_a, while the tariffs in the other two countries (τ_b and τ_c) are unchanged.

Proposition 2. *For the three country Bertrand Model in which good are differentiated and are strategic substitutes and firms face increasing marginal cost in production, a tariff reduction by country a against all other countries causes*

- *incomplete tariff pass-through, a decrease in country b and c's tariff-inclusive export prices in country a* ($\frac{dp_{ba}}{d\tau_a} > 0$, $\frac{dp_{ca}}{d\tau_a} > 0$)*, but an increase in the tariff-exclusive prices* ($\frac{dp^*_{ba}}{d\tau_a} < 0$, $\frac{dp^*_{ca}}{d\tau_a} < 0$)*,*

- *two-way tariff spillover, an increase in country b's export price in country c* ($\frac{dp_{bc}}{d\tau_a} < 0$) *and an increase in country c's export price in country b* ($\frac{dp_{cb}}{d\tau_a} < 0$)*.*

Proof: Totally differentiating the nine first order conditions given by (46), dividing through by $d\tau_a$, applying Cramer's rule, and using the condition $B > 2D$ yields the signs of the following comparative static effects for a change in τ_a: (1) for goods sold in country a, $\frac{dp_{ba}}{d\tau_a} > 0$, $\frac{dp_{aa}}{d\tau_a} > 0$, $\frac{dp_{ca}}{d\tau_a} > 0$; (2) for goods produced in country b, $\frac{dp^*_{ba}}{d\tau_a} < 0$, $\frac{dp_{bb}}{d\tau_a} < 0$, $\frac{dp_{bc}}{d\tau_a} < 0$; (3) for goods produced in country c, $\frac{dp^*_{ca}}{d\tau_a} < 0$, $\frac{dp_{cb}}{d\tau_a} < 0$, $\frac{dp_{cc}}{d\tau_a} < 0$. QED.

The intuition of these results is also straightforward and similar to that stated above for the non-MFN tariff case. The only difference is that, since country a now reduces its tariff against both country b and country c, all the previous results for country b now also hold for country c.

the assumption of segmented markets. One might wonder whether we can get the same result with the assumption of constant marginal cost and integrated markets, or whether market integration will lead to the same tariff spillover effect. The answer is: in that case, we will get a tariff spillover effect that is opposite to what we get here, that is, a unilateral tariff reduction by country a against country b causes a decrease in country b's export price in country c ($\frac{dp_{bc}}{d\tau_{ba}} > 0$). The intuition is the following. With the assumption of integrated markets, there should be no arbitrage of the product produced by firm b. A unilateral tariff reduction by country a against country b leads to a reduction of the tariff-inclusive price that firm b charges in country a (p_{ba}), and thus the price that firm b charges in country c (p_{bc}) should also reduce, so that there is no arbitrage opportunity for the product between country a and country c. However, this opposite tariff spillover effect ($\frac{dp_{bc}}{d\tau_{ba}} > 0$) contradicts the empirical findings of this paper, which will be shown in section 5.

[50]Note that proposition 2 below only requires MFN tariff in country a, but not necessarily MFN tariffs in the other two countries.

In sum, the model predicts that when a country reduces its tariff (either non-MFN tariff or MFN tariff) against another country, then a country that exports to the liberalizing country not only raises its tariff-exclusive prices to the liberalizing country (incomplete tariff pass-through), but also raises its prices to third countries (tariff spillover).

One might wonder whether the tariff spillover effect is larger or smaller for MFN tariffs than for non-MFN tariffs. The model does not have an unambiguous prediction about this. The reason is as follows. On the one hand, in the MFN tariff case, country a's tariff reduction applies to both country b and country c (MFN tariffs), and thus both countries will export more to country a. Hence the increase of country b's export to country a would be lower than that in the non-MFN tariff case (due to the competition of country c). Therefore the marginal cost of production in country b, and hence its export price in country c (p_{bc}), will increase by a smaller amount than in the non-MFN tariff case. On the other hand, in the MFN tariff case, since country c also increases its export to country a, the production cost and domestic price in country c (p_{cc}) also increase, which will push up country b's export price in country c (the second reason for the increase of p_{bc}). Thus country b's export price in country c (p_{bc}) will increase more than in the non-MFN tariff case. Due to these two opposite effects, the actual increase of country b's export price in country c (tariff spillover) in the MFN tariff case could be either lower or higher than that in the non-MFN tariff case, depending on which effect is dominant.

3. Empirical Specification

I use the following benchmark specification to test the tariff spillover effect:

$$\begin{aligned}\Delta lnP^{*}_{ifc't} =& \alpha + \beta_1 \Delta ln(1+\tau_{ic't}) + \beta_2 \Delta ln(1+\tau_{ict}) \\ & + \gamma_1 \Delta lnER_{c'(t-1)} + \gamma_2 \Delta lnER_{c(t-1)} \\ & + \eta_1 \Delta lnRGDP_{c't} + \eta_2 \Delta lnRGDP_{ct} \\ & + \phi \Delta lnCPI_t + \theta lnTFP_{f(t-1)} \\ & + FE + \varepsilon_{ifc't}.\end{aligned} \tag{47}$$

Here $\Delta lnP^*_{ifc't}$ is the change of log (tariff-exclusive) export price of the product i exported by firm f in the home country to a third country c' from period $t-1$ to period t. $\Delta ln(1+\tau_{ic't})$ is the change of log gross (ad-valorem) tariff rate by the third country c' on the product, and $\Delta ln(1+\tau_{ict})$ is the change of log gross (ad-valorem) tariff rate by the liberalizing country c on the product. Thus coefficient β_1 measures "tariff absorption elasticity", i.e., the percentage change in the tariff-exclusive price that the domestic firm charges in the third country c' in response to a one percent change of the gross tariff rate in that third country; coefficient β_2 measures "tariff spillover elasticity", i.e., the percentage change in the tariff-exclusive price that the domestic firm charges in the third country c' in response to a one percent change of the gross tariff rate in the liberalizing country c. According to the model, both β_1 and β_2 should be negative[51].

$\Delta lnER_{c'(t-1)}$ is the change of log exchange rates between the third country c' and the home (export) country, and $\Delta lnER_{c(t-1)}$ is the change of log exchange rates between the liberalizing country c and the home (export) country. The impact of a currency depreciation of the export country is similar to that of a tariff reduction of the import country. If export prices are denoted in the currency of the home (export) country, and if exchange rate is expressed as units of foreign (import) country currency per unit of the home (export) country currency, then coefficient γ_1 measures "exchange rate absorption elasticity", and γ_2 measures "exchange rate spillover elasticity". Both γ_1 and γ_2 should be negative[52], as β_1 and β_2. Notice that the exchange rate changes are those in period $t-1$ (changes from period $t-2$ to $t-1$). This is because exchange rate changes typically have a lag effect, as shown in the exchange rate pass-through literature.

$\Delta lnRGDP_{c't}$ is the change of log real GDP of the third country c', and $\Delta lnRGDP_{ct}$ is the change of log real GDP of the liberalizing country c. Coefficient η_1 measures "demand pass-through elasticity", and η_2 measures "demand spillover elasticity". An increase of the real GDP of an importing country should lead to an increase of its import quantities and an increase of its import prices. The increased production of the exporting

[51] A negative tariff absorption elasticity implies a less-than-one tariff pass-through elasticity, i.e., incompleteness of tariff pass-through.

[52] Again, a negative exchange rate absorption elasticity implies a less-than-one exchange rate pass-through elasticity, i.e., incompleteness of exchange rate pass-through.

country should then lead to an increase of its marginal production costs and export prices to all other countries. Hence both η_1 and η_2 should be positive.

$\Delta lnCPI_t$ is the change of log consumer price index of the home (export) country, which measures the inflation rate and production cost changes in the home (export) country.[53] Coefficient ϕ should be positive, since an increase in production cost of the home (export) country leads to an increase in the export prices. $lnTFP_{f(t-1)}$ is the total factor productivity of the exporting firm in the base year $t-1$, which is the unique firm-level explanatory variable in the regression. The model is at the product level, and thus does not have any prediction about the firm-level impacts on export prices. Thus, I do not have any prior for the sign of coefficient θ. FE denotes various fixed effects.

4. Data

The main dataset that I use in the empirical analysis is the U.S. Linked/Longitudinal Firm Trade Transaction Database (LFTTD), which was assembled by Bernard, Jensen and Schott (2008). The database links all individual U.S. import and export transactions to the respective U.S. firms. The dataset comes from two sources: one is the foreign trade data (FTD) assembled by the U.S. Census Bureau (for exports) and U.S. customs(for imports), which contains all U.S. international trade transactions between 1992 and 2005 inclusive; the other one is the Longitudinal Business Database (LBD) of the U.S. Census Bureau, which records annual employment and survival information for most U.S. establishments. I use the U.S. export data in the LFTTD database in the period 1995-1999, the applied period of Uruguay Round, to investigate how tariff reduction of foreign countries caused by Uruguay Round passes through to US export prices to liberalizing countries and spills over to U.S. export prices to third countries. For each export transaction, the database records its product category (at HS10 level), quantity, (tariff-exclusive) value, U.S. export firm, year and month in which the transaction occurs, whether the transaction

[53]Note that this change of production cost is a change of cost caused by inflation, which is represented by the shift of the entire marginal cost curve. It is different from the increasing marginal cost I am exploring — a change of cost caused by the change of output quantity, which is represented by the movement along the same marginal cost curve.

is an arm's length transaction or takes place between related parties[54], etc.

Export price changes are computed from export values and quantities. Before constructing export prices, I clean the data in the following way. (1) I drop transactions 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 higher or lower 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 transactions is quite different from normal arm's length transactions. For the rest of transactions, I construct firm-level prices (unit values) as $P^*_{ifct} = V_{ifct}/Q_{ifct}$, 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. The constructed export prices are tariff-exclusive since export values are tariff-exclusive. Among all product-firm-country-year cells for which I constructed export prices, I keep those surviving in two consecutive years, and computer changes of log prices $\Delta lnP^*_{ifct} = lnP^*_{ifct} - lnP^*_{ifc(t-1)}$. For each destination country c in a specific "product-export firm-year" cell, I not only have the price change for this country (ΔlnP^*_{ifct}), but also have the price change for each of its "other" (third) countries c' to which the firm also exports ($\Delta lnP^*_{ifc't}$). I then construct the average price change for all of its "other" (third) countries, and denote it as $\Delta lnP^*_{ifC't} = \sum_{c'} \Delta lnP^*_{ifc't}/N_{c'}$, where $N_{c'}$ is the number of "other" (third) countries to which the firm also exports, and the capital C' denotes all these "other" (third) countries.

The tariff data contain the tariff rates of other countries against U.S. exports of different products. The data were collected by the World Integrated Trade Solution (WITS) 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 HS8 or HS10 products within a same HS6 category. For each

[54]Related-party transactions refer to trade between U.S. companies and their foreign subsidiaries and trade between U.S. subsidiaries of foreign companies and their affiliates abroad.

HS6 category, the data includes the maximum, minimum, and mean tariff rates of all HS8 or HS10 products within the category. I only include HS6 categories within which there is no tariff variation (that is, the maximum, minimum and mean tariff rates are all identical), since it is only for these HS6 categories that I can calculate accurate tariff change over time for products at HS10 level[55], $\Delta\tau_{ict}$. Similar to price change, for each destination country c in a specific "product-year" cell, I not only have the tariff change for this country ($\Delta ln(1+\tau_{ict})$), but also have the tariff change for each of its "other" (third) countries c' to which the firm also exports ($\Delta ln(1+\tau_{ic't})$). I then construct the average tariff change for all of its "other" (third) countries, and denote it as $\Delta ln(1+\tau_{iC't}) = \sum_{c'} \Delta ln(1+\tau_{ic't})/N_{c'}$. These tariff changes are then merged to U.S. export price changes of corresponding products to corresponding destination countries.[56]

The data for exchange rates and real GDP come from the Penn World Table. The data for CPI are from International Financial Statistics (IFS) of the International Monetary Fund. For exchange rates and real GDP, I also construct the changes to third countries using the similar method that I used for export price and tariff changes.

Firm productivity (TFP) is constructed from the U.S. Census of Manufactures (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). Here I only use the data for 1997, since the price changes and tariff changes that I am looking at are for the period 1995-1999. From this data I construct plant-level TFP from the typical constant returns to scale index form. 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, and is then merged to the U.S. export price changes of corresponding firms.

[55] For a HS6 industry within which there is tariff variation across HS8 or HS10 products, I can only calculate the change of average tariff rate for the HS6 industry, but not the accurate tariff change for each HS8 or HS10 product.

[56] Note that the final sample size is constrained by the following operations: (i) As mentioned in the beginning of this subsection, many export transactions were dropped when we constructed the export price and their changes. (ii) When we combined the export price changes with tariff changes, we also dropped HS6 products within which there is tariff variation.

5. Empirical Results

In this section, I will present the empirical results. First of all, I would like to mention that the results presented below are very preliminary and qualitative, with only signs and significance of the estimates. Moreover, the regressions only use some of, but not all of, the regressors mentioned in section 3. Thus both the regressions and results need to be improved. However, these preliminary results show that the predictions of the model are supported by the empirical evidence.

I test the model predictions with two samples. One sample is the full sample for U.S. exports during the period 1995-1999.[57] In the other sample, I only include "country-year" pairs with large tariff changes for certain products during the same period. More specifically, for each "country-year" pair in the full sample, I calculate the number of 6-digit HS products with tariff change higher than 5 percentage points. Then I pick the first six "country-year" pairs with the highest numbers of products with large tariff changes[58]; but for each of these "countries-year" pairs, I keep all products no matter whether they have large tariff change or not. The purpose of choosing this sample is to ensure that there are enough observations with large 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. Table 1 is a list of the "country-year" pairs that I choose, in order of the number of HS6 products with tariff change higher than 5 percentage points.

Table 2a contains the OLS regression results for the sub-sample. The dependent variable in all regressions is $\Delta lnP^{*}_{ifC't}$, the average log price change of product i exported by firm f to all countries other than country c from period $t-1$ to t. In the first column, I only include one regressor, $\Delta ln(1+\tau_{ict})$, the change of log gross tariff rate on product i by country c from period $t-1$ to t. I also include a country fixed effect to capture the impact of country-specific shocks such as exchange rate changes and GDP changes

[57]The model predicts that tariff spillover effect exists for both MFN tariffs and non-MFN tariffs, while it does not have an unambiguous prediction on which case has a larger effect. However, it would be worthwhile to empirically check this by dividing the full sample into two subsamples, one with MFN tariffs and the other one with non-MFN tariffs, and comparing the tariff spillover effects in the two subsamples.

[58]These six "country-year" pairs have much more HS6 products with larger-than-5-percentage-points tariff change than other "country-year" pairs.

of country c on firm's export prices to third countries[59]. The coefficient is negative and significant, which is consistent with the model prediction and implies that tariff spillover effect does exist: when country c reduces its tariff rate on a product, U.S. exporting firms raise their exporting prices to third countries. According to the model, the main reason is that the increased export and production quantities caused by the tariff reduction in country c lead to an increase of marginal production costs of U.S. exporting firms and in turn an increase of their export prices to all destination countries.

In the second column, I add the firm-specific control variable, $lnTFP_f$, the log total factor productivity of exporting firms in 1997 and its interaction with the tariff change. Now the coefficient for the tariff change term measures the tariff spillover effect for a specific firm with log of productivity equal to 1, but it is not significant. The coefficient for the firm productivity is not significant neither, which implies that firm productivity does not have a significant impact on the price change to third countries. However, the coefficient for the interaction term is negative and significant, which means that firm productivity does have a significant impact on tariff spillover effect; more specifically, more productive firms on average have higher tariff spillover effect. A possible explanation is: more productive firms have a competitive advantage in the export market; when they face a tariff reduction of country c, they increase their export and production quantities by a larger magnitude, and hence their marginal production costs and export prices to all markets increase by a larger magnitude.

In the third and fourth columns, I repeat the regressions in the first two columns, but change the country fixed effect to product fixed effect to capture the impact of product-specific shocks on export price changes. As you can see from the table, the regression results are similar to what I got before: first, tariff spillover effect does exist and is significant; second, tariff spillover effect is larger for more productive firms. In the last two columns, I repeat the same regressions, but include both the country and the product fixed effects. The regression results are still similar to before, with the significance of

[59]The country fixed effect here captures the "exchange rate spillover effect" and "demand spillover effect" mentioned in section 3, but not the "exchange rate pass-through" or "demand pass-through". Since in the sub-sample I only have one period change for each of the selected countries, I only need a country fixed effect instead of a "country-year" fixed effect to capture these impacts.

tariff spillover elasticities becomes a little bit lower.

Next, I explore tariff spillover effect on export quantities, which is called "tariff deflection" in Bown and Crowley (2007). In table 2b, I repeat all the regressions in table 2a, but change the dependent variable to $\Delta lnQ^*_{ifC't}$, the average change of log export quantity of product i exported by firm f to all countries other than country c from period $t-1$ to t. In columns (1), (3) and (5), the coefficient for the tariff change term is positive and significant, indicating that tariff deflection does exist: when country c reduces its tariff rate on a product, U.S. exporting firms reduce their export quantities to third countries. This should be because they now charge higher export prices than before due to the increased marginal costs caused by the increased export and production quantity to the liberalizing country. In columns (2), (4) and (6), the coefficient for the interaction term between tariff change and firm TFP is positive and significant, indicating that tariff deflection is larger for more productive firms. This should be due to the fact that more productive firms raise their export prices more, as indicated above. Hence, the results on tariff deflection on export quantities further confirm the results on tariff spillover effect on export prices.

Finally, I test tariff spillover effect and tariff deflection with the full sample. Table 3a and table 3b contains the regression results for the full sample, in the same structure as that in tables 2a and 2b. Comparing the results in these two tables with those in tables 2a and 2b, I can easily find that they are very similar to each other, except that the significance of both the coefficients for the tariff change term (in columns (1), (3), and (5)) and the coefficients for its interaction with firm productivity (in columns (2), (4), and (6)) now becomes lower. This might be due to the fact that in the full sample, there are relatively less large tariff changes which induce price changes. However, I still confirms the existence of tariff spillover effect (columns (1), (3), (5) in table 3a) and its dependence on firm productivity (columns (2), (4) and (6) in table 3a), as well as the existence of trade deflection and its dependence on firm productivity (in table 3b). As indicated above, the latter further confirms the former.

6. Conclusions

This paper extends the studies in incomplete tariff pass-through and trade deflection by exploring how tariff changes of a country impact trade prices between its trade partners. Using a simple three-country Bertrand competition model, I show that, when a foreign country reduces its tariffs, domestic exporting firms not only raise their tariff-exclusive prices toward the liberalizing country, which is known as "incompleteness of tariff pass-through" in the literature, but also raise their prices toward third countries, which I refer to as "tariff spillover effect". This is true for both a MFN tariff reduction and a non-MFN tariff reduction. The "tariff spillover effect" on export prices toward third countries is comparable to "trade deflection" on export quantities toward third countries, which was studied by Bown and Crowley (2007). As in their paper, the existence of the "tariff spillover effect" also depends on the assumption of increasing marginal cost: tariff reduction of a foreign country leads to an increase of export quantities and total output of domestic exporting firms, which leads to an increase of their marginal costs and export prices to all export destinations. Using the newly available transaction level data on U.S. exports during the period 1995-1999, the applied period of Uruguay Round, I find empirical evidence for the "tariff spillover effect". The empirical results also show that this effect is larger for firms with higher productivity.

References

Bagwell, K. and Staiger, W. (1997), "Multilateral Tariff Cooperation during the Formation of Free Trade Areas", *International Economic Review*, 38, 291-319.

Bagwell, K. and Staiger, W. (1999), "An Economic Theory of GATT", *American Economic Review*, 89, 215-248.

Bagwell, K. and Staiger, W. (2004), "Multilateral Trade Negotiations, Bilateral Opportunism and the Rules of GATT/WTO", *Journal of International Economics*, 63, 1-29.

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

Bernard, A. B., Jensen, J. B., and Schott, P. (2008), “Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trades Goods”, forthcoming in Dunne, T., Jensen, J. B., and Roberts, M. J., eds *Producer Dynamics: New Evidence from Micro Data*, University of Chicago Press.

Bown, C. and Crowley, M. (2007), “Trade Deflection and Trade Depression”, *Journal of InternationAL Economics*, 72, 176-201.

Broda, C., Limão, 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.

Ethier, W. J. (2004), “Political Externalities, Nondiscrimination, and a Multilateral World”, *Review of International Economics*, 12, 303-320.

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

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

Levy, P. (1997), “A Political-Economic Analysis of Free-Trade Agreements”, *American Economic Review*, 87, 506-519.

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.

Ludema, R. and Yu, Z. (2011a),“Tariff Pass-through, Firm Heterogeneity, and Product Quality”, *Working Paper.*

Ludema, R. and Yu, Z. (2011b),“Tariff Pass-through and Market Structure”, *Working Paper.*

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.

Romalis, J. (2002), ”NAFTA’s and CUSFTA’s Impact on North American Trade”, *University of Chicago - GSB mimeo*, July 2002.

Vine, J. (1950),“The Customs Union Issue”, *Carnegie Endowment for International Peace*, New York.

Tables

Table 1. "Countries-year" Pairs in the Sub-sample: with Large Tariff Change ($|\Delta\tau_{ict}| > 0.05$) in a Wide Range of HS6 Products

Country	year	Ranking in terms of number of HS6 products with $|\Delta\tau_{ict}| > 0.05$
China	1996-1997	1
Pakistan	1998-1999	2
Bangladesh	1998-1999	3
Egypt	1997-1998	4
Indonesia	1995-1996	5
Philippines	1995-1996	6

Table 2a. Tariff Spillover Effect: sub-sample

Dependent Variable	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta ln(1+\tau_{ict})$	$-$***	$+$	$-$***	$-$	$-$*	$-$
$lnTFP_f$		$-$		$-$		$-$
$\Delta ln(1+\tau_{ict}) \times lnTFP_f$		$-$***		$-$***		$-$***
Fixed effects	country	country	product	product	country +product	country +product

Note: *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 2b. Trade Deflection: sub-sample

Dependent Variable	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta ln(1+\tau_{ict})$	$+$***	$-$	$+$***	$+$	$+$***	$+$
$lnTFP_f$		$-$		$-$		$+$
$\Delta ln(1+\tau_{ict}) \times lnTFP_f$		$+$***		$+$***		$+$***
Fixed effects	country	country	product	product	country +product	country +product

Note: *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 3a. Tariff Spillover Effect: Full Sample

Dependent Variable	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$	$\Delta lnP^*_{ifC't}$
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta ln(1+\tau_{ict})$	$-$*	$+$	$-$*	$-$	$-$*	$-$
$lnTFP_f$		$+$		$+$		$+$
$\Delta ln(1+\tau_{ict})$ $\times lnTFP_f$		$-$**		$-$*		$-$*
Fixed effects	country ×year	country ×year	product	product	country×year +product	country×year +product

Note: *, **, and *** denote the 10, 5, and 1 percent of significance levels.

Table 3b. Trade Deflection: Full Sample

Dependent Variable	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$	$\Delta lnQ^*_{ifC't}$
Regressors	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta ln(1+\tau_{ict})$	$+$*	$-$	$+$*	$-$	$+$*	$+$
$lnTFP_f$		$-$		$-$		$-$
$\Delta ln(1+\tau_{ict})$ $\times lnTFP_f$		$+$*		$+$*		$+$*
Fixed effects	country ×year	country ×year	product	product	country×year +product	country×year +product

Note: *, **, and *** denote the 10, 5, and 1 percent of significance levels.