Technology, Trade, and Quality Slopes*

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Abstract

We investigate the factors that, in addition to preferences, affect the extent to which richer households pay more for a given durable good with respect to their expenditures on nondurables, defined as the quality slope. We show theoretically and confirm empirically that the quality slope decreases in the cost elasticity of quality. Given that this elasticity varies across countries, the quality slope also depends on tariffs. Specifically, it increases in the tariff on middle-income exporters (higher elasticity) and decreases in the tariff on imports from high-income OECD exporters (lower elasticity) to the U.S.

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1 Introduction

Richer households buy more expensive, presumably better, higher-quality goods.[1] This fact–referred to as non-homothetic consumption patterns under quality differentiation–has become an important part of international trade since Linder (1961).[2] Indeed, there is strong evidence that richer countries buy and sell more expensive goods (see, e.g., Schott, 2004; Hallak, 2006; Hummels and Klenow, 2005) and that their imports are less price sensitive (see, e.g., Hummels and Lugovskyy, 2009). Overall, the fit between theoretical predictions and international trade data is much better if models include quality differentiation and non-homothetic consumption (e.g., Hummels and Klenow, 2005; Fieler, 2011).

The importance of non-homotheticity has been shown for calculating quality-adjusted price indexes. Using detailed U.S. household-level data, Bils and Klenow (2001) derived and estimated product-specific quality slopes for durable goods, defined as the elasticity of the unit price that the household paid for the quality-differentiated durable good with respect to the household's nondurable expenditures. They found substantial heterogeneity in the quality slopes across goods, and showed that ignoring this heterogeneity results in upward-biased inflation estimates. They obtained slope heterogeneity by assuming asymmetric preferences across goods, and, since preferences are not likely to change often, their slopes are time invariant.

In this paper, we show that the quality slope for a given good also depends on its cost elasticity of quality (EoQ). Moreover, if this elasticity varies across countries, the quality slope is also affected by international trade. In particular, if 'northern' countries have a lower EoQ than 'southern' countries, then the tariffs imposed on the northern and southern goods have opposite effects on the quality slopes and unit price inflation. Empirically, we

[1]Bils and Klenow (2001) showed that richer households buy more expensive durable goods, while Handbury (2013) showed that richer households buy more expensive grocery items. See also Bils and Klenow (2001) for a literature review of the studies that find a positive correlation between prices and quality by using the hedonic quality measures for goods such cars, computers, cell phones, etc.

[2]See Markusen (2013) and Feenstra and Romalis (2014) for the related reviews of the recent literature.

match the detailed household-level data from the U.S. Consumer Expenditure Survey (CE) with the highly disaggregated U.S. imports data, and confirm our theoretical predictions. Our framework is instrumental in explaining the observed significant intertemporal variation in quality slopes. Importantly, international trade and changes in trade policy have a significant effect on quality slopes, which should be taken into account when calculating quality-adjusted unit-price inflation rates.

Theoretically, to build intuition, we start with an autarky model with a homogenous numeraire and a single quality-differentiated good with non-unitary EoQs.[3] The novel prediction of the model is that the quality slope depends not only on the demand side parameter, the elasticity of substitution (EoS), but also on the supply-side EoQ. Consistent with our theoretical predictions, our estimates of quality slopes increase in the EoS and decrease in the EoQ estimated by Feenstra and Romalis (2014).[4]

In autarky, preferences and technology are rather stable over time, and so is the quality slope. However, if a country imports varieties of a vertically-differentiated good from different exporters who use different technologies, the average quality slope will be affected by the variety mix available for consumption. Tariffs on imported goods will then serve as demand shifters, and changes in tariffs would affect the mix of varieties and thus the quality slope.

We explore this intuition by allowing for technological differences between two countries, North and South, each of which exports the quality-differentiated good to a third country, Home. Similar to Flam and Helpman (1987), we assume that the cost elasticity of quality is lower in North than in South. As a result, the purchases made by the households buying northern goods generate a steeper quality slope than the purchases made by households buying southern goods, whereas the (weighted) average quality slope depends on the shares

[3]In a different context, the importance of the EoQ was previously emphasized by Baldwin and Harrigan (2011), who showed that in a heterogeneous-firm model, the sorting of firms via quality versus productivity is determined by the magnitude of the EoQ.

[4]Feenstra and Romalis (2014) were the first to estimate the EoQs using a multi-country dataset. Previous estimates of EoQs were obtained from country-specific datasets: Crozet et al. (2012) estimated EoQ for French champagnes; Nguyen (2009) estimated EoQs for Danish exports.

of northern and southern goods in Home's import mix. Consequently, the tariffs on northern goods will decrease the average quality slope as they decrease the share of northern goods in Home, while the tariffs on southern goods will have the opposite effect. We also show that the technological diffusion from North to South decreases the main effect of the tariff on the average quality slope.

To confirm our theoretical predictions, we first utilize the U.S. CE for the years 1989–2007, which include unit expenditures on finely disaggregated goods and household demographics. Using these data, we employ Bils and Klenow (2001)'s methodology to estimate the annual quality slopes for 56 consumer durable goods and 63 apparel, footwear, and textile goods (henceforth, AFT goods). Importantly, our estimates show that the quality slopes are not time invariant.

Next, we match the estimated quality slopes with the highly disaggregated product-level "U.S. Imports of Merchandise" data and regress the quality slopes on the average U.S. tariffs on goods from high-income Organization for Economic Co-operation and Development (OECD) and middle-income countries (North and South, respectively). The estimates are both statistically and economically significant, and their signs are consistent with our theoretical predictions. Namely, a 1% decrease in the tariff on durable goods from high-income countries *increases* the median quality slope for durables by 3.4%, while a 1% decrease in the tariff on goods from middle-income countries *decreases* it by 1.9%. Our back-of-the-envelope calculations indicate that changes in quality slopes due to variation in tariffs contribute about 20% to the unmeasured product quality growth in unit price inflation. We also confirm that the effects of tariffs on quality slopes become weaker as middle-income countries open up to imports from high-income countries and foreign direct investment (FDI) inflow, which we use as proxies for technology diffusion.

We contribute to the vast theoretical (see, e.g., Flam and Helpman, 1987; Stokey, 1991; Fajgelbaum et al., 2011) and empirical (e.g., Muhammed Dalgin and Trindade, 2008; Choi et al., 2009; Hummels and Lee, 2012; Fajgelbaum and Khandelwal, 2014) literatures on how non-homothetic preferences and the within-country income heterogeneity affect patterns of, and gains from, international trade. We complement these literatures by showing that international trade, in turn, affects the households' expenditure patterns. In addition, our empirical results provide indirect evidence supporting the underlying assumption of many of these models that the less-developed South has a higher EoQ than the more-developed North.

We also contribute to the discussion on measuring quality in the international trade literature. While some papers have approximated quality with unit values (e.g., Schott, 2004; Hummels and Skiba, 2004; Hallak, 2006; Fieler, 2012; Johnson, 2012), this approach has been challenged on the grounds that unit values alone might be misleading, since they also depend on costs and markups, and that other characteristics of traded goods, such as quantity,[5] firm characteristics (e.g., Verhoogen, 2008; Manova and Zhang, 2012a), and trade restrictions (e.g., Aw and Roberts, 1986; Boorstein and Feenstra, 1987; Feenstra, 1988) should be considered when measuring quality.

We corroborate the evidence (see, e.g., Bils and Klenow, 2001; Handbury, 2013) that richer households buy more expensive goods, which provides support to the argument by Oxenfeldt (1950) that "quality has meaning only in relation to price," since the highest available quality is rarely optimal to buy for most households. That is, while the market share is a useful indicator of quality within a narrow price range, for large price differences, the within-country income distribution should be taken into account.[6]

The paper proceeds as follows. The next section introduces the theoretical model and its predictions to guide the empirical analysis. Sections 3 and 4 discuss the data, empirical

[5] See, e.g., Hummels and Klenow (2005), Khandelwal (2010), and Amiti and Khandelwal (2013). Hallak and Schott (2011) use trade deficits, which implicitly account for both trade price and quantity.

[6] Choi et al. (2009) demonstrated that a connection exists between the within-country income distribution and the distribution of import prices. Their paper, however, did not focus on the methodology of quality measurement. We leave this direction for further research.

strategy, and results. Section 5 concludes the paper.

2 Theoretical Framework

In the model with the asymmetric constant elasticity of substitution (CES) preferences[7] defined over one unit of a quality-differentiated durable good and composite homogenous numeraire, we want to show that the extent to which richer households pay more for the durable good with respect to their expenditure on the numeraire–the quality slope–in addition to preferences, also depends on the technological parameter, the cost elasticity of quality. In autarky, we show that the quality slope (i) increases in the elasticity of substitution (EoS) and (ii) decreases in the EoQ of the durable good. Furthermore, in the presence of the cross-country asymmetry in technologies and international trade, the average quality slope will increase in tariffs on imports from countries with lower EoQ and decrease in tariffs on imports from countries with higher EoQ.

2.1 Autarky

A household $h = 1, 2, ..., H$ chooses the quantity of the numeraire composite c_h and the quality z_h of a quality-differentiated good to maximize the utility:

$$u_h = \frac{c_h^{1-1/\sigma}}{1-1/\sigma} + \frac{z_h^{1-1/\varepsilon}}{1-1/\varepsilon} \qquad \sigma, \varepsilon > 1, \tag{1}$$

[7]Dixit and Stiglitz (1977) were the first to discuss the properties of the asymmetric CES preferences; they did not, however, discuss any applications relating to quality differentiation. More recently, Bils and Klenow (2001) used asymmetric CES preferences to derive quality slopes, and Fieler (2011) used them to introduce nonhomotheticity and quality differentiation into Eaton and Kortum (2002)'s framework.

where σ is the EoS of the numeraire and ε is the EoS of the quality-differentiated good. The budget constraint is given as follows:

$$c_h + p_h(z_h) \leq I_h, \tag{2}$$

where the price of the numeraire is normalized to one, $p_h(z_h)$ is the price paid by h for quality z_h, and I_h is household h's income.

Labor is the only production factor. The numeraire is produced by a perfectly competitive sector, whereas one unit of the numeraire requires one unit of labor. These assumptions allow us to normalize the wage to one.

The cost of producing quality z is given by $C(z) = \alpha z^{\gamma}$, where $\gamma > 1$ is the cost elasticity of quality and $\alpha > 0$.[8] Firms behave competitively, and thus the price of a quality-differentiated good with quality z is equal to its production cost:

$$p(z) = \alpha z^{\gamma}, \tag{3}$$

from which the marginal cost of quality is $\frac{dp(z)}{dz} = \alpha\gamma z^{\gamma-1}$.

Since household h buys only one unit of the quality-differentiated good, in equilibrium, the ratio of the marginal utility of the numeraire c_h over the marginal utility of quality z_h is equal to the price of the numeraire over the marginal cost of quality z_h:

$$\frac{c_h^{-1/\sigma}}{z_h^{-1/\varepsilon}} = \frac{1}{\alpha\gamma z^{\gamma-1}}. \tag{4}$$

Using equations (3) and (4), we substitute for $p_h(z_h)$ with the numeraire in the budget

[8] The corresponding production function of quality is given by $z = (l/\alpha)^{1/\gamma}$. Feenstra and Romalis (2014) used the same functional form of the production function of quality, where $0 < \frac{1}{\gamma} < 1$ reflects diminishing returns to quality.

constraint (2) to derive the implicit solution to the utility maximization problem:

$$\begin{cases} z_h = \left(\alpha\gamma c_h^{-1/\sigma}\right)^{-1/(1/\varepsilon+\gamma-1)} \\ c_h + \alpha\left(\alpha\gamma c_h^{-1/\sigma}\right)^{-\gamma/(1/\varepsilon+\gamma-1)} = I_h \end{cases}. \tag{5}$$

As we can see, the budget constraint is highly non-linear in the numeraire, implying a non-homothetic consumption pattern: the income elasticity of demand for the numeraire is not constant. Moreover, due to non-linearity, it is not feasible to derive an explicit solution for the equilibrium quantity of the numeraire and the quality and prices of the differentiated goods. What is feasible, however, is deriving the explicit solution for the ratio of the income elasticities of demand for quality over the income elasticity of demand for the numeraire. Given that the price of the numeraire is normalized to one, this ratio will represent the elasticity of the price paid for the quality-differentiated good with respect to the expenditure on the numeraire. Following Bils and Klenow (2001) we define this ratio as a quality slope θ:

$$\theta_h \equiv \frac{\%\Delta p_h}{\%\Delta I_h} \Big/ \frac{\%\Delta c_h}{\%\Delta I_h} = \frac{\%\Delta p_h}{\%\Delta c_h}.$$

In our model, the quality slope can be derived from equations (3) and (4) as:

$$\theta_h = \frac{\partial \ln p_h}{\partial \ln c_h} = \frac{\gamma}{\sigma\left(1/\varepsilon + \gamma - 1\right)}. \tag{6}$$

Importantly, the quality slope is a convenient characterization of the expenditure pattern, since (i) it can be derived in explicit form, and (ii) as it follows from equation (6), it is constant and symmetric for all households independent of their income: $\theta_h = \theta \quad \forall h$.

Proposition 1 *The quality slope θ increases in the elasticity of substitution and decreases in the cost elasticity of quality of a quality-differentiated good* $\left(\frac{\partial\theta}{\partial\varepsilon} > 0; \quad \frac{\partial\theta}{\partial\gamma} < 0\right)$.

Proof. It follows directly from equation (6). ■ Our first result is consistent with Bils and

Klenow (2001). The negative effect of the EoQ on θ, however, is a new result. It relies on relaxing Bils and Klenow (2001)'s assumption on setting the EoQ equal to one.

2.2 Model with Trade

In this section, we introduce international trade and allow technologies to differ across country-exporters. The model is set from Home's perspective, which imports the quality-differentiated good from two other countries, North and South (indexed by N and S, respectively), and pays for it with the numeraire. As in autarky, a Home household h with income I_h chooses the quantity of the numeraire c_h and quality z_h to maximize utility:

$$u_h = \frac{c_h^{1-1/\sigma}}{1-1/\sigma} + \frac{z_h^{1-1/\varepsilon}}{1-1/\varepsilon} \qquad s.t. \quad c_h + p(z_h) \leq I_h, \tag{7}$$

where $p(z)$ is the price of quality z and the price of the numeraire good is normalized to one.

In all three countries, the production of one unit of the numeraire requires one unit of labor, the parameters of the model are such that all countries produce the numeraire, and its trade cost is set to zero. These assumptions allow us to normalize the wages in all countries to one. For simplicity, we assume that Home does not produce the quality-differentiated good and imports it from both North and South.[9] The labor unit requirements for producing quality z in North and South are given as follows:

$$C_N(z) = \alpha_N z^{\gamma_N} \qquad C_S(z) = \alpha_S z^{\gamma_S} \qquad \gamma_S > \gamma_N > 1 \quad \alpha_N > \alpha_S > 0, \tag{8}$$

Note that South has a lower unit cost multiplier ($\alpha_N > \alpha_S$), while North has a lower EoQ ($\gamma_N < \gamma_S$). This cost structure implies that South possesses both absolute and comparative advantages in lower qualities, while North has them in higher qualities.

In the differentiated sector, firms behave competitively, and the trade cost is given by the

[9]The main predictions of the model hold if Home also produces differentiated products.

tariff expressed in iceberg form: $\tau_i > 1$, $i \in \{N, S\}$. Thus, the delivered price at Home is equal to the corresponding labor unit requirement times the iceberg trade cost:

$$p_N(z) = \alpha_N z^{\gamma_N} \tau_N \qquad\qquad p_S(z) = \alpha_S z^{\gamma_S} \tau_S \tag{9}$$

Similar to Flam and Helpman (1987), the supply price of quality z in Home is

$$p(z) = \min\{\alpha_N z^{\gamma_N} \tau_N, \alpha_S z^{\gamma_S} \tau_S\}. \tag{10}$$

Since South has a comparative advantage in lower quality products, while North has it in higher quality products, equation (10) represents the price profile in a competitive equilibrium. From equation (9), we can also find the quality level $\bar{z}$, which is equally costly to produce when either northern or southern technologies are employed: $\bar{z} = \left(\frac{\alpha_N}{\alpha_S} \frac{\tau_N}{\tau_S}\right)^{1/(\gamma_S - \gamma_N)}$. That is, the southern comparative advantage will be in qualities below $\bar{z}$, while the northern comparative advantage will be in qualities above $\bar{z}$.

As in Flam and Helpman (1987), there is a kink in the budget set that creates a discontinuous relationship between prices and income. South will specialize in the low quality $z < z^-$ and North will specialize in the high quality $z > z^+$ with $z^- < \bar{z} < z^+$. There is an income level I_d such that a household with income I_d is indifferent between buying quality z^- from South and quality z^+ from North. No demand would exist for quality levels between z^- and z^+. Households with an income equal to or above I_d will choose from the qualities produced by North, and their utility maximization problem will have the following solution:

$$z_N = \left(\alpha_N \tau_N \gamma_N c^{-\frac{1}{\sigma}}\right)^{\frac{-1}{1/\varepsilon + \gamma_N - 1}} \qquad c + \alpha_N \tau_N \left(\alpha_N \tau_N \gamma_N c^{-\frac{1}{\sigma}}\right)^{\frac{-\gamma_N}{1/\varepsilon + \gamma_N - 1}} = I \qquad \forall I \geq I_d. \tag{11}$$

Households with an income below I_d will choose from the qualities produced by South, and their utility maximization problem will have the following solution:

$$z_S = \left(\alpha_S \tau_S \gamma_S c^{-\frac{1}{\sigma}}\right)^{\frac{-1}{1/\varepsilon+\gamma_S-1}} \qquad c + \alpha_S \tau_S \left(\alpha_S \tau_S \gamma_S c^{-\frac{1}{\sigma}}\right)^{\frac{-\gamma_S}{1/\varepsilon+\gamma_S-1}} = I \qquad \forall I < I_d. \tag{12}$$

Similar to the autarky model, equations (9), (11), and (12) allow us to derive the quality slopes for the northern and southern-produced qualities:

$$\theta_N = \frac{\partial \ln p_N}{\partial \ln c} = \frac{\gamma_N}{\sigma\left(1/\varepsilon + \gamma_N - 1\right)} \qquad \theta_S = \frac{\partial \ln p_S}{\partial \ln c} = \frac{\gamma_S}{\sigma\left(1/\varepsilon + \gamma_S - 1\right)}. \tag{13}$$

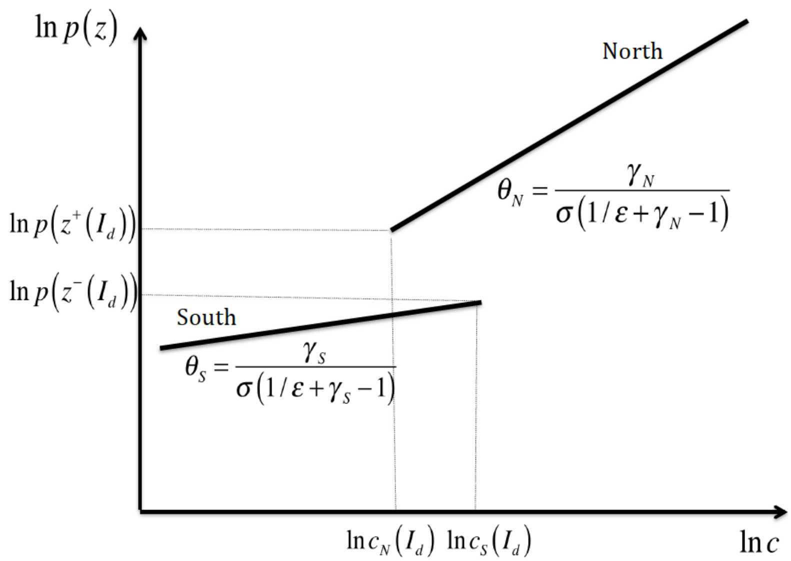

Figure 1: Equilibrium quality slopes.

Figure 1 illustrates the above equilibrium. The northern quality slope is larger than the southern one, since the northern EoQ is lower than the southern one ($\gamma_N < \gamma_S$).

To derive testable predictions, we are interested in calculiting the average slope, since the origins of the products are not specified in our data. To this end, we define the shares of households buying goods from South and North as $F(I_d)$ and $1 - F(I_d)$, respectively, where

$F(I)$ denotes the cumulative distribution function of income levels of Home households. The weighted-average quality slope can then be defined as a weighted sum of θ_S and θ_N:

$$\bar{\theta} = F(I_d)\frac{\gamma_S}{\sigma\left(1/\varepsilon + \gamma_S - 1\right)} + \left[1 - F(I_d)\right]\frac{\gamma_N}{\sigma\left(1/\varepsilon + \gamma_N - 1\right)}. \tag{14}$$

This result allows us to explore the effect of tariffs on the average quality slope.

Lemma 1 *The share of households buying southern-produced quality, $F(I_d)$, decreases in the Home's tariff on southern goods and increases in the tariff on northern goods.*

Proof. See Appendix A. ■ Lemma 1 identifies the channel through which tariffs affect the average quality slope. We formalize these effects in Proposition 2 as follows:

Proposition 2 *The average quality slope increases in the tariff on southern goods and decreases in the tariff on northern goods.*

Proof. See Appendix A. ■ Proposition 2 extends the intuition of Proposition 1 and shows that in the presence of international trade and cross-country technological differences, the quality slope is affected by tariffs. It also helps to explain changes in the quality slope even if we keep preferences and country-specific technologies fixed.

The sensitivity of the quality slope to variation in tariffs depends on the extent of the technological differences between North and South, which can be reduced by technological diffusion. To consider this aspect, we model technological diffusion by allowing South to obtain northern elasticity of quality for a certain continuous quality segment, between the lowest produced quality z_{min} and certain point z_T, while keeping the other cost parameter, α_S, unchanged. Since $\alpha_S < \alpha_N$, South will have a comparative advantage in $[z_{min}, z_T]$, and the average quality slope, defined by equation (14), can be redefined as follows:

$$\bar{\theta}_T = \begin{cases} \overbrace{\frac{F(I_T)\gamma_N}{\sigma(1/\varepsilon + \gamma_N - 1)}}^{\text{Tech. diffusion}} + \overbrace{\frac{[F(I_d) - F(I_T)]\,\gamma_S}{\sigma(1/\varepsilon + \gamma_S - 1)}}^{\text{southern tech.}} + \overbrace{\frac{[1 - F(I_d)]\,\gamma_N}{\sigma(1/\varepsilon + \gamma_N - 1)}}^{\text{northern tech.}} & \text{if } z_T < z^-(I_d) \\ \underbrace{\frac{\gamma_N}{\sigma(1/\varepsilon + \gamma_N - 1)}}_{\text{No southern tech.}} & \text{if } z_T \geq z^-(I_d) \end{cases}, \quad (15)$$

where I_T denotes the income at which the household is indifferent between the qualities produced under the original and diffused technologies. Note that if $z_T < z^-(I_d)$, the segment $[z_{min}, z_T]$ is smaller than the original set of qualities produced by South, and the qualities in the segment $(z_T, z^-(I_d)]$ will still be produced with the southern EoQ, γ_S. If, on the other hand, $z_T > z^-(I_d)$, the all qualities will be produced with the northern EoQ, γ_N.

Proposition 3 *Ceteris paribus, the technological diffusion from North to South reduces the sensitivity of the average quality slope to changes in tariffs.*

Proof. See Appendix A. ■

3 Empirics – Estimating Quality Slopes

We start our empirical exercises by employing Bils and Klenow (2001)'s methodology to estimate the quality slope for each good and year in our sample. There are three important differences between our empirical analysis and that of Bils and Klenow (2001). First, instead of pooling over all years in the sample to obtain one quality slope for each good, we calculate 19 three-year moving average slopes. This allows us to focus on the intertemporal variation of the estimated slopes. Second, we employ data from 1988 to 2008 instead of 1980–1996. This will allow us, in the second stage of our empirical exercise, to match the obtained estimated slopes with the detailed U.S. data on tariffs, available only from 1989 onwards. Finally, our analysis includes a larger set of goods than that of citetbils.

3.1 Data and Descriptive Statistics

We use the 1988–2008 U.S. Household Expenditure Surveys[10] to estimate the annual quality slopes for 119 household goods[11]. The CE has a rotating sample of about 5,000 households[12] for each year, consisting of four quarterly surveys. To obtain annual expenditures, we aggregate four quarters of expenditures and drop those households that do not report their purchases in all four quarters. Consequently, the yearly number of households in our sample is less than 5,000.

The surveys contain information on the unit prices paid by households for each of the 119 goods consumed in our sample. Following the classification of the National Income and Product Accounts, we identify 56 durable goods. We classify the remaining 63 goods as apparel, footwear, and textile (AFT) goods.[13] We also use data on nondurable expenditures,[14] and household demographics such as the U.S. regions (Northeast, Midwest, South, and West), urban versus rural residence area, the total number of persons and the number of children in the household, the average age of the head of household, and dummy variables for single-male or single-female headed households.[15]

Table 1 provides the summary statistics of household nondurable expenditures (in constant 1988 U.S. dollars) as well as the number of households in our sample for each year. The inflation-adjusted average nondurable expenditures increase steadily from 1988 to 2008. The magnitudes of the standard deviation indicate that there is a large variation in annual nondurable expenditures across households. Furthermore, given that the median is on average

[10] http://www.bls.gov/cex/

[11] While the CE dataset contains information on a larger set of goods, we restrict our sample to goods that households buy throughout the entire sample period.

[12] The number of households in the sample changes over the years. For example, in 2012, the survey had a rotating sample of 7,000 households.

[13] The list of the goods and the classification split are available in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html.

[14] Following Bils and Klenow (2001), we (i) use nondurable expenditures as a proxy for permanent income, and (ii) exclude AFT goods from the nondurable expenditures.

[15] Some demographic indicators change across interviews within a year. For these cases, we retain the information provided by the household in its first interview.

Table 1: Household Nondurable Expenditures (Constant 1988 U.S. Dollars)

Year	Mean	Median	St.Dev	No. obs
1988	16,987	15,019	9,758	2,633
1989	17,490	15,149	10,352	2,623
1990	17,035	14,718	10,021	2,701
1991	17,298	15,037	10,162	2,743
1992	16,689	14,505	9,837	2,727
1993	16,693	14,452	9,906	2,761
1994	16,844	14,847	10,013	2,702
1995	16,433	13,947	11,073	1,936
1996	17,562	15,148	10,294	1,835
1997	17,023	14,966	9,756	2,856
1998	16,893	14,912	9,661	2,809
1999	17,959	15,385	13,113	3,410
2000	17,581	15,311	10,334	3,830
2001	18,624	15,754	19,515	3,642
2002	18,739	16,120	11,461	3,874
2003	18,276	15,798	12,048	3,964
2004	19,049	16,522	15,006	2,760
2005	20,269	17,547	12,531	2,492
2006	20,070	17,243	12,559	3,472
2007	20,429	17,352	15,912	3,301
2008	20,642	12,788	17,819	3,311

Source: household Expenditure Survey 1988-2008

15% lower than the mean, the distribution is skewed to the left.

The data also reveal a significant variation in the unit prices of the durable goods. In 1989, the price dispersion, measured as the ratio of the 90th percentile over the 10th percentile of unit prices, varies between 5 and 53 for durable goods and between 4 and 39 for AFT goods. The magnitudes are similar for other years in our sample.[16]

Overall, these data are uniquely suited for an analysis of how the quality slopes in the U.S. evolve over time, and especially in response to U.S. trade policy. First, we observe the prices that households pay for each unit bought rather than the unit values (i.e., total value divided by quantity) utilized in most studies in the trade literature. Second, we have data on households' nondurable expenditures and a number of household demographics that allow us to control for household-specific preferences for quality. Lastly, the time series from 1989 to 2007 includes the period characterized by very rapid tariff liberalization.

Our data have some limitations. First, the CE consists of data collected from interviews with a sample of households, and it is subject to errors resulting from the inability or unwillingness of the respondents to provide accurate information, as well as from differences in the interviewers' abilities and mistakes in recording or coding. Nevertheless, we are confident in

[16]Price variation for each good in 1989 and 2007 is available in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html.

the quality of the data because many academic researchers and policymakers have used them and, more importantly, because they are primary data used to regularly revise the household price index market basket of goods and services. Second, while the CE data provide very detailed information on household purchases and demographics, they do not allow us to identify the origins of the goods. Thus, if the share of either southern or northern imports is insignificant for some products, our predictions might be rejected due to the lack of variation in the origins of production.

3.2 Estimation and Results

We estimate a separate quality slope θ_{gt} for each year t and good g. The identification of a good-specific quality slope relies on how the paid price of that good varies with the household's nondurable expenditures. That is, if the paid price increases in household's nondurable expenditures, the quality slope estimates are positive. In our data, quantity equals unity, and thus the higher price that richer households pay indicates that they buy a higher-quality variety. Since the quality slope is defined as the elasticity, both the unit price p_{hgt} paid by household h and h's expenditures or non-durables c_{ht} are in logs:

$$\log p_{hgt} = \text{Const}_{gt} + \theta_{gt} \log c_{ht} + \sum_i \beta^i_{gt} H^i_{ht} + \epsilon_{hgt}, \tag{16}$$

where, following Bils and Klenow (2001), our set of control variables, denoted by $\sum_i H^i_{ht}$, includes dummies for region and city versus rural, to control for price differences across space, as well as household-specific variables to capture heterogeneity in preferences: the total number of persons and the number of children in the household, the average age of the head of household and that age squared, and dummy variables for single male-headed households and for single female-headed households.[17]

[17] The model described in section 2 assumes the same preferences across households. However, this could be an oversimplified assumption and we attempt to correct for the potential heterogeneity in households'

To correct for measurement errors in the households' reported nondurable expenditures, we estimate the goods' quality slopes by two-stage least squares (2SLS).[18] In the 2SLS, c_{ht} represents the household's nondurable expenditures in the last two quarters and we instrument for these expenditures using the household's nondurable expenditures in the first two quarters. For each good and year in the sample, we perform the estimations with three years of combined data and include year dummies. For example, we estimate the 1989 quality slope by pooling over the data from 1988, 1989, and 1990. In doing so, the estimation smoothes out the coefficients, and each good's quality slope is the average quality slope for the three years and it is centered in the year for which the results are presented.[19]

The vast majority of the estimated quality slopes are positive and statistically significant at the 10% level or better, whereas 88 out of 119 goods have statistically significant quality slopes in all 19 years of our sample.[20] For seven goods, the slopes are negative in some years, but they are also statistically insignificant. For some goods, a low number of observations results in statistically insignificant estimates for some years (e.g., Playground equipment, Silver serving pieces, Window air conditioners, Girls' uniforms, etc.). In the second stage of our empirical exercise, we address this issue by weighting the observations by the inverse of their respective standard errors so that the quality slopes estimated with better precision have higher weights.

There is a great deal of variation in the estimated quality slopes across the goods in the sample. The quality slopes estimates are the largest for Window coverings, Curtain and drapes, Jewelry, Outdoor furniture, and Rugs, and the smallest for Clothes washers, Clothes dryers, Microwave ovens, Lawn and garden equipment, Vacuums, Boys' hosiery, and Girls'

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preferences by incorporating some household characteristics.

[18] According to Bils and Klenow (2001), misreported nondurable expenditures might bias the estimates toward zero, and two-stage least squares is necessary to correct the bias. They did find that the OLS estimates are slightly lower than the 2SLS estimates.

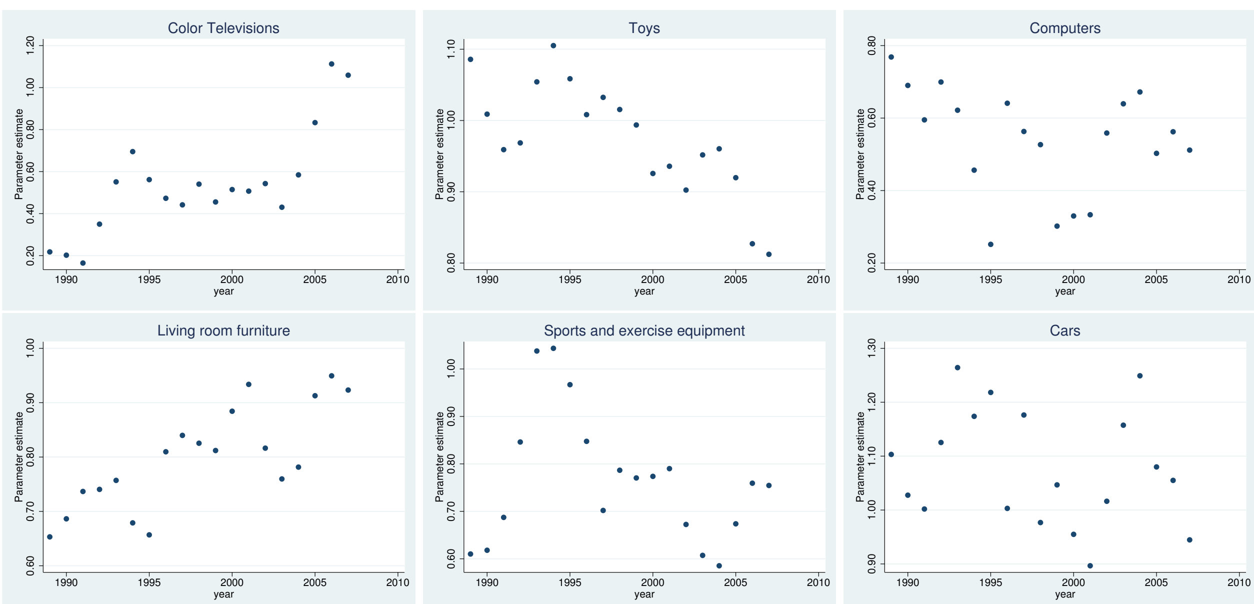
[19] The number of households buying a good varies significantly across years. Using three years of data gives us a larger number of households in the sample to identify the yearly quality slope for each good.

[20] Summary statistics of the slope estimates for each good as well as the number of households buying each good in a given year are available in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html.

and Men's uniforms. These estimates are consistent with Bils and Klenow (2001)'s findings.

The model in section 2 assumes away variation in markups due to horizontal product differentiation. However, as Bils and Klenow (2001) highlighted, the estimated quality slopes are valid even in the presence of horizontal differentiation as long as the markups are not correlated with households' expenditures on nondurables.[21]

The estimated slopes exhibit varying degrees of intertemporal variation: the coefficient of variation is between 0.06 and 0.2 for most of the AFT goods, while it is significantly higher than that for most durables. We fail to detect a common dynamic pattern in the estimated slopes. Instead, there is a mix of increasing and declining trends with a lot of variation across products. For example, Figure 2 shows that Color televisions and Living room furniture experience an overall increasing trend, while Toys and Sports and exercise equipment experience an overall declining trend. Other goods, such as Computers and Cars, do not exhibit any overall trend. Thus, we are not likely to explain the variation with some



(a) Increasing Trend (b) Decreasing Trend (c) No Trend

Figure 2: Examples of Different Trend Patterns across Estimated Quality Slopes.

[21]Goldberg (1996) does not find evidence of a correlation between the markups of cars and a household's income.

common factor, such as gradual technological progress, for all goods.

3.3 Preferences, Technology, and Quality Slopes

Before trying to explain the intertemporal variation in quality slopes with international trade, we first assess the plausibility of our estimates by using the predictions of our autarky model, which distinguishes between the effects of preferences and technology on the quality slope. According to Proposition 1, the quality slope increases in the elasticity of substitution and decreases in the cost elasticity of quality. We test these predictions by regressing the quality slope on the EoS and EoQ estimated by Feenstra and Romalis (2014).

Feenstra and Romalis (2014) used bilateral trade and tariff data from the UN Comtrade Database, raw TRAINS Database, and World Trade Organization's Integrated Database covering multiple country pairs from 1984 to 2011. Their paper was the first to estimate the multi-country[22] returns-to-quality parameter at the 4-digit SITC level, which is an inverse of the EoQ in our paper. For each SITC good, the estimate is constant across countries and time periods and it can be interpreted as the average EoQ across exporters and years. Together with the EoQ, Feenstra and Romalis (2014) also estimate the EoS at the 4-digit SITC level.[23]

First, we match the 119 goods from the CE data with the closest 4-digit level SITC according to their verbal descriptions. For many of the goods in the sample, we do not find a one-to-one mapping. For the goods with multiple 4-digit level SITC codes that map into one CE good, we average the EoQ and EoS estimates across all 4-digit SITC codes and match the average to the CE good. For the goods with multiple CE goods that correspond to one 4-digit level SITC code, we assign the 4-digit level SITC code to each CE good. There are a

[22] Crozet et al. (2012) estimate the EoQ for French champagnes, while Nguyen (2009) estimates the EoQs for Danish exports.

[23] See Feenstra and Romalis (2014) for the details on the estimation procedure. Broda and Weinstein (2006) and Soderbery (2014) also estimate the EoS for the United States, but, for consistency, we draw from the estimates in Feenstra and Romalis (2014) obtained from worldwide trade data.

few goods for which we find no corresponding 4-digit SITC code. After dropping the latter goods from our sample, 100 goods remaining.

Next, we regress the log of our product- and year-specific quality-slope estimates ($\hat{\theta}_{gt}$) on the log of the product-specific estimates of the EoS ($\hat{\sigma}_g$) and EoQ ($\hat{\gamma}_g$) with year-fixed effects to control for time-specific factors affecting all quality slope estimates:[24]

$$\log \hat{\theta}_{gt} = \underset{(0.14)^{**}}{-0.60} - \underset{(0.12)^{*}}{0.30} * \log \hat{\gamma}_g + \underset{(0.05)^{**}}{0.16} * \log \hat{\sigma}_g + D_t + \epsilon_{gt}. \tag{17}$$

The corresponding R^2 is 0.12 and the number of observations is 2,673.

In the cross-sectional specification, we average our yearly quality slope estimates for each good and regress the log of the product-specific average of the quality slope estimates ($\bar{\hat{\theta}}_g$) on the log of the product-specific estimates of the EoS ($\hat{\sigma}_g$) and the EoQ ($\hat{\gamma}_g$) as follows:

$$\log \bar{\hat{\theta}}_g = -\underset{(0.14)^{**}}{0.67} - \underset{(0.11)^{*}}{0.27} * \log \hat{\gamma}_g + \underset{(0.05)^{**}}{0.16} * \log \hat{\sigma}_g + \epsilon_g, \tag{18}$$

The corresponding R^2 is 0.18 and the number of observations is 100.

The results from both specifications confirm our theoretical predictions: the quality slope increases in the EoS and decreases in the EoQ. In order to provide a quantitative interpretation of our results, we also estimate the standardized (beta) coefficients of the EoS and EoQ, which are 0.33 and (-0.21), respectively. These estimates allow us to attribute 61% of the explained variation in quality slopes to preferences and 39% to technology.

4 The Effect of Tariffs on Quality Slopes

In this section, we test whether, as predicted by our model, the estimated quality slopes increase in thetariffs on southern-produced goods and decrease in the tariffs on northern-

[24]Observations are clustered by CE good.

produced goods. We choose the high-income members of the OECD to represent the technologically more advanced North, and upper-middle income and lower-middle income countries, as classified by the World Bank, to represent South.[25]

4.1 Data and Descriptive Statistics

We obtain tariff rates for the CE goods in our sample from the U.S. Imports of Merchandise data published by the U.S. Census Bureau. The dataset contains information on U.S. imports from 223 countries and covers the period, 1989–2007. It includes the country of origin, values, and duties paid, with the commodity detail level up to the 10-digit Harmonized System (HS) classification, which allows us to match the goods in the CE data to U.S. imports. In particular, we match the 119 goods from the CE data with the closest 10-digit level HS categories according to their descriptions. For most goods, we find one-to-one mapping. For several AFT items, for which one-to-one mapping is not available, we construct many-to-one mapping by matching several CE goods with one HS category.[26]

We let North be represented by 30 high-income OECD members, referred to as high-income countries (henceforth, HICs), and let South be represented by 77 upper-middle and lower-middle income countries, referred to as middle-income countries (henceforth, MICs). For each good, we calculate a trade-weighted average ad-valorem tariff rate separately for the HICs and MICs. By construction, the variation in these tariffs also relies on compositional effects and thus can potentially be driven by a few outliers. In order to address this concern, we calculate the weighted-average tariff rates for each exporter for 1989 and 2007 separately

[25] A more detailed description follows below. The full list of countries in each group is presented in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html. We exclude poor countries from our analysis, since we want to ensure a minimum level of technological development for a given country sufficient for quality differentiation.

[26] For apparel, the CE dataset classifies goods separately for men, women, boys, and girls, while the U.S. dataset differentiates them only by gender. Moreover, the U.S. data lack gender-specific HS codes for accessories, hosiery, and footwear; thus, we combine the corresponding men's and women's CE categories into one category.

for durables and AFT goods.[27]

We observe that the tariff rates decline for most countries between 1989 and 2007, and thus the decline in the aggregated tariffs on imports from HICs and MICs is not likely to be caused by outliers. We also find that for nearly all exporter countries in our sample, the trade-weighted average tariff rates for AFT goods are considerably higher than for durable goods in 1989, and they remain higher at the end of the sample period.

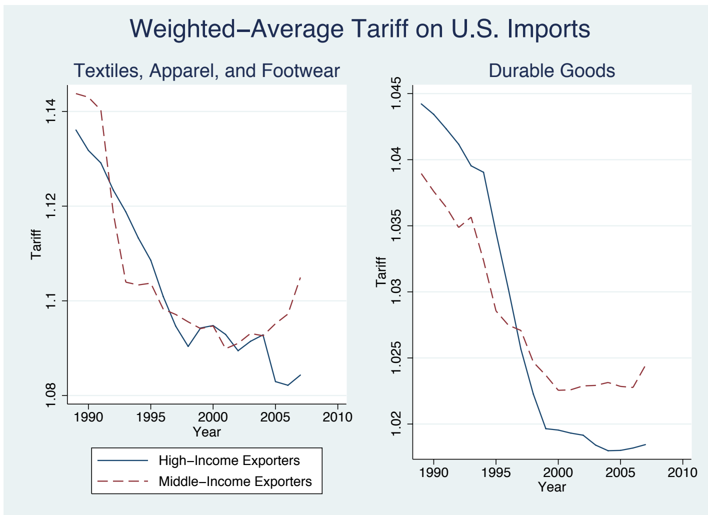


Figure 3: Trends in the U.S. Tariffs across Goods and Exporters

Between 1989 and 2007, for almost all products in our sample, there is a significant decrease in the trade-weighted tariffs on imports from both HICs and MICs. These tariffs are not decreasing at exactly the same rate, and thus, as illustrated in Figure 3, we observe a significant variation in the relative high- over middle-income tariffs both across goods and over time.[28] This is important because the empirical test of our predictions relies on having sufficient variation in tariffs on imports from both HICs and MICs.

While we do not directly employ import shares in our regression analysis, theoretically

[27]The calculated weighted tariffs for each product are available in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html.

[28]The product-level statistics on the intertemporal variation in tariffs is available in the Online Appendix at http://mypage.iu.edu/ vlugovsk/research.html.

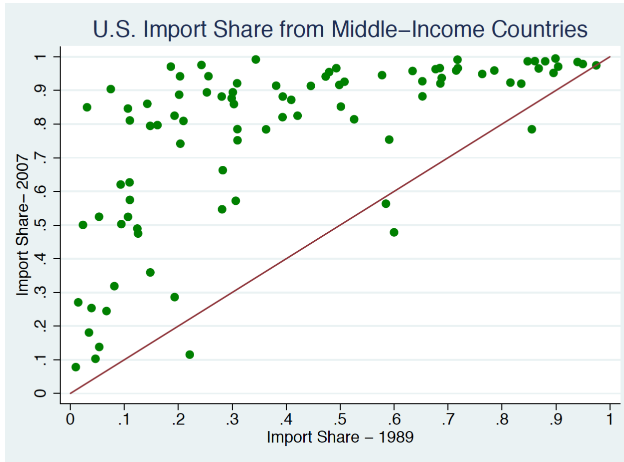


Figure 4: U.S. Product-Level Import Shares from Middle-Income Countries in 2007 and 1989.

we rely on changes in northern and southern import shares. Thus, it is important to confirm that both tariffs and the import shares vary over time. Figure 4, which plots the U.S. import share from middle-income exporters in 2007 against 1989, confirms this variation, since most of the goods are quite distant from the 45 degree line.

In order to account for the effects of technological diffusion, we draw data on the country-specific imports of manufacturers and FDI inflows from the World Bank's World Development Indicators. For each good and year, we construct two weighted averages (both as a percentage of GDP): (i) the average of FDI inflows into MICs and (ii) the average of imports of manufactures into MICs, where the weights are these countries' export shares to the U.S. These constructed variables vary across years and goods. The variation across goods is driven by the variation in the share of the MICs' exports to the U.S. Table 2 indicates that there is a great deal of variation in both variables and that the correlations between these variables and trade-weighted average tariffs are rather low.

Table 2: Summary Statistics of Proxies for Technological Diffusion, FDI and Imports of Manufactures to Middle-Income Countries (as percent of GDP).

X (percent of GDP)	Mean	Median	St. Dev	Corr(X,τ^H)[1]	Corr(X,τ^M)[2]
All Goods					
FDI	2.88	2.91	1.09	-0.19	-0.16
Imports of Manufactures	19.60	19.22	6.12	0.09	-0.03
Durable Goods					
FDI	3.02	3.13	1.13	-0.16	-0.01
Imports of Manufactures	19.60	18.95	6.84	-0.21	-0.15
Apparel, Footwear, and Textiles					
FDI	2.66	2.57	1.01	-0.19	-0.22
Imports of Manufactures	19.58	19.68	4.81	0.07	-0.03

[1] τ^H is the log of trade-weighted average U.S. tariff on goods from High-income countries;
[2] τ^M is the log of trade-weighted average U.S. tariff on goods from Middle-income countries.

4.2 Estimation and Results

Baseline Model

Following Proposition 1, we estimate the effects of tariffs from high- and middle-income exporters on the estimated quality slope $\hat{\theta}_{gt}$ using the following specification:

$$\hat{\theta}_{gt} = \text{Const} + D_g + D_t + \beta_1 \log \tau^H_{gt} + \beta_2 \log \tau^M_{gt} + \epsilon_{gt}, \tag{19}$$

where subscripts g and t denote good g and time period t, respectively, and τ^H_{gt} and τ^M_{gt} are the trade-weighted average ad-valorem tariff rates on goods originating from high- and middle-income countries, respectively. D_g and D_t are the good and year fixed effects included to control for varying households' quality preferences across goods but constant over time, and year fixed effects to control for year-specific factors common to all goods,respectively.

We correct for heteroskedasticity across goods by estimating equation (19) with the weighted least squares, where the weights are the inverse of the estimated standard errors. The technological gap between HICs and MICs might be more pronounced for durables, the production of which might require a higher degree of technological sophistication, than for the AFT goods. Durables are also less likely to be affected by non-tariff barriers (such as, e.g., quotas) than the AFT goods. Thus, we expect our predictions to fit the data better in the durables sample than in the AFT sample.

Column (1) of Table 3 provides our baseline set of estimates, which are based on specification (19). The empirical results are consistent with our theoretical predictions: the U.S. quality slopes decrease in tariffs on imports from HICs and increase in tariffs on imports from MICs ($\hat{\beta}_1 < 0, \hat{\beta}_2 > 0$). As expected, the magnitudes of the estimated coefficients are much smaller for the AFT goods than for the durables.

To interpret the magnitudes of the estimates, we first calculate the absolute effect of a 1% increase in tariffs on the quality slope, and then compare it against the median quality slope of the corresponding group. The results are presented in Table 4. For durables, the median quality slope decreases by 3.4% for a 1% increase in the tariff on goods from HICs and increases by 1.9% for a 1% increase in the tariff on goods from MICs. The corresponding magnitudes are much smaller for the AFT goods: −1% and 0.8%, respectively.

Technological Diffusion

As stated in Proposition 3, the technological diffusion from North to South is expected to decrease the sensitivity of the quality slopes to tariffs. To account for this possibility, we augment specification (19) with an interaction term between the average tariff on imports from the MICs and a proxy of technological diffusion X_{gt} (we discuss the proxies below):

$$\hat{\theta}_{gt} = \text{Const} + D_g + D_t + \beta_1 \log \tau_{gt}^H + \beta_2 \log \tau_{gt}^M + \beta_3 X_{gt} + \beta_4 \log \tau_{gt}^M X_{gt} + \epsilon_{gt}. \tag{20}$$

Table 3: The Effect of Tariffs on the U.S. Quality Slopes, 1989-2007.

Dependent Variable – estimated product-level annual U.S. quality slopes;
X is Imports of Manufactures (percent of GDP) into Middle-Income Countries in specification (2) and (3);
X is FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5).

	(1)	(2)	(3)	(4)	(5)
	Baseline	X=Imp. of Manuf.		X=FDI	
All goods					
Log of tariff on High-Income Countries	-0.68***	-0.69***	-0.76***	-0.68***	-0.74***
	(0.16)	(0.16)	(0.17)	(0.16)	(0.17)
Log of tariff on Middle-Income Countries	0.79***	0.80***	1.46***	0.76***	1.01***
	(0.14)	(0.14)	(0.31)	(0.14)	(0.19)
X		-0.00	0.00	0.01	0.01**
		(0.00)	(0.00)	(0.00)	(0.00)
Log of tariff on Middle-Income Countries * X			-0.03**		-0.11**
			(0.01)		(0.05)
Constant	0.70***	0.72***	0.68***	0.69***	0.67***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
Adj. R-squared	0.71	0.71	0.72	0.71	0.72
No. Obs.	2252	2252	2252	2252	2252
Durable goods					
Log of tariff on High-Income Countries	-2.49***	-2.14**	-1.80**	-2.53***	-2.33***
	(0.81)	(0.87)	(0.88)	(0.81)	(0.83)
Log of tariff on Middle-Income Countries	1.40***	1.33**	2.85***	1.39**	1.66***
	(0.54)	(0.54)	(0.66)	(0.54)	(0.52)
X		-0.00	-0.00	0.01	0.01
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			-0.10***		-0.19
			(0.04)		(0.14)
Constant	0.73***	0.73***	0.69***	0.72***	0.70***
	(0.06)	(0.06)	(0.09)	(0.06)	(0.06)
Adj. R-squared	0.66	0.66	0.66	0.66	0.66
No. Obs.	1074	1074	1074	1074	1074
Apparel, Footwear, and Textiles					
Log of tariff on High-Income Countries	-0.56***	-0.53***	-0.52***	-0.57***	-0.46***
	(0.16)	(0.17)	(0.17)	(0.16)	(0.16)
Log of tariff on Middle-Income Countries	0.46***	0.43***	0.03	0.44***	-0.14
	(0.14)	(0.14)	(0.43)	(0.14)	(0.24)
X		0.00	-0.00	0.01	-0.01
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			0.02		0.21***
			(0.02)		(0.07)
Constant	0.72***	0.71***	0.75***	0.72***	0.78***
	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)
Adj. R-squared	0.76	0.76	0.76	0.76	0.76
No. Obs.	1178	1178	1178	1178	1178

Notes:
1.Tariff rates are trade-weighted average of ad-valorem tariff rates, where weights are the import share from each country.
2.Exporters are classified in HICs and MICs using the World Bank classification.
3.Regressions are weighted by the inverse of the standard errors of QEC estimates.
4.Year and product fixed effects in all regressions.
5.Robust standard errors, significance * .10 ** .05 *** .01.

Table 4: Absolute and Relative Effects of Tariffs on the Quality Slope

Sample of Goods	Median Quality Slope	Tariff on imports from ...	The Effect of 1% Higher Tariff on the Quality Slope	
			Absolute*	Relative**
All Goods	0.60	North	-0.0068	-1.1%
		South	0.0079	1.3%
Durable Goods	0.73	North	-0.0249	-3.4%
		South	0.0140	1.9%
AFT Goods	0.56	North	-0.0056	-1%
		South	0.0046	0.8%

Notes: *Calculated as the Estimated Coefficient from the corresponding line of Table 3, column 1 times 10. Semi-elasticity, since the left hand side is in levels, while the right-hand side is in logs.
** Calculated relative to the Median Quality Slope reported in column (2).

where we consider two proxies of technological diffusion X_{gt}: (i) imports of the intermediates to the MICs and (ii) FDI inflows into the MICs.[29] Both channels are motivated by the recent empirical evidence of the positive effect of imports and FDI on export prices and quality in developing countries (e.g., Manova and Zhang, 2012a,b; Amiti and Khandelwal, 2013; Fan et al., 2014; Harding and Javorcik, 2012).

From the model, we expect the technological diffusion to counteract the main (positive) effect of the southern tariff on the quality slope. That is, we expect a negative estimate of the coefficient on the interaction term. The estimates reported in columns (3) and (5) of Table 3 support our predictions for the samples of all goods and durables, but not for the sample of the AFT goods. We consider it to be a positive result, since our analysis does not take into account reductions in non-tariff barriers over this period, which are significant for the AFT goods with the phase-out of the Multi-Fiber Agreement (MFA). Other studies found evidence of quality downgrading in these goods following the phase-out of MFA. We believe that our estimates are consistent with these findings.

[29] Our proxies for these variables are constructed in terms of the percentage of GDP. A more detailed description and statistics summary of the proxies are provided in Section 4.1.

To assess the quantitative effect of technological diffusion, we consider a counterfactual of no technological diffusion from North to South. In particular, we use the estimates reported in columns (3) and (5) of Table 3 and set the imports of manufacturers to zero for column (3) and the FDI inflows to zero for column (5). We report the economic significance only for durables, which are our main interest in this exercise. In the absence of imports of manufactures, a 1% increase in the U.S. tariff on durable goods from MICs would increase the median quality slope by a striking 3.9%. This is more than twice as high as the baseline 1.9% reported in Table 4, which indirectly shows a strong effect of manufacturers' imports on the technological diffusion. The corresponding effect in the absence of FDI is somewhat lower, 2.27%, but it is still higher than the baseline 1.9%.

4.3 Quality Slopes, Tariffs, and Unit Price Inflation

Bils and Klenow (2001) showed that for time-invariant quality slopes, prices grow faster for goods with steeper quality slopes. In this section, we extend their analysis by showing that if quality slopes vary over time, an increase in the quality slope for a given good increases the rate at which the price of this good increases.

To achieve this goal, we calculate the unit price for each good and regress it on our quality slope estimates. To calculate the unit price inflation, we first construct the three-year centered moving average of the prices of each good,[30] and then calculate the first differences of the log of the averaged unit prices for each good. Next, we regress the unit price inflation on our quality slope estimates and good fixed effects. The results are consistent with our theory. The estimates presented in column (1) of Table 5 show that if the quality slope for a given good increases over time, the corresponding inflation changes as well. Quantitatively, for a median yearly increase in quality slope of 0.06 points, the yearly unit price inflation

[30]The three-year moving average price minimizes the impact of outliers in the data.

increases by 0.42%.[31] This provides a strong argument for re-estimating the quality slopes on an annual basis rather than relying on the time-invariant quality slopes.

What share of the effect of quality slopes on unit-price inflation is due to variation in tariffs? To separate the effect of tariffs on unit price inflation (through quality slopes) from other factors (e.g., changes in technology), we first calculate the fitted quality slopes—the quality explained by the tariff rates on goods from high-income and middle-income countries:

$$\tilde{\theta}_{gt} = \hat{\beta}_1 \log \tau_{gt}^H + \hat{\beta}_2 \log \tau_{gt}^M, \tag{21}$$

where subscripts g and t denote good g and time period t, respectively; $\tilde{\theta}_{gt}$ is the fitted quality slope, and τ_{gt}^H and τ_{gt}^M are the trade-weighted average ad-valorem tariff rates on goods originating from HICs and MICs, respectively, and $\hat{\beta}_1$ and $\hat{\beta}_2$ are our baseline estimates reported in column (1) of Table 3.

Next, we regress the unit price inflation on the obtained fitted values of $\tilde{\theta}_{gt}$. Column (2) of Table 5 shows that fitted quality slopes have a positive effect on unit price inflation: for a median yearly increase in quality slope of 0.003 points, the yearly unit price inflation increases by 0.08%. That is, ignoring the tariff-related annual changes in quality slopes might lead to a median bias of 0.08% in annual inflation rates for the goods with increasing quality slopes.[32] By comparing this number to the 0.42% due to the overall effect of quality slopes on unit price inflation, changes in tariff rates contribute about 20% to the unmeasured product quality growth in unit price inflation for the goods with decreasing quality slopes.

[31] The median yearly decrease in quality is -0.06, and as a result, the magnitude of the effect is the same for the goods with decreasing quality.

[32] The results remain robust if we also control for changes in tariff rates together with fitted quality.

4.4 Robustness Checks

First, we confirm that the above results are robust to the use of the one-year lag of imports of manufactures to the MICs and the one-year lag of FDI inflows to the MICs as measures of technology diffusion. The results are presented in Tables 6, which show that the sign and significance patterns are consistent with our baseline proxies of technology diffusion.

Second, we experiment with alternative measures of tariffs. In particular, in specifications (19) and (20), we use simple average tariffs instead of trade-weighted average tariffs. As a result, we present Table 8 showing that the coefficients change slightly in magnitude, but the patterns of the signs and significance levels are consistent with our original results, reported in Table 3.

Third, we remove China and Mexico from our sample. During the time period in our sample, two major episodes of trade liberalization occur with the U.S. and China and Mexico, its main trade partners. To check whether our results are driven mainly by trade liberalization with China and Mexico, we exclude China and Mexico from our sample of exporters and re-estimate specifications (19) and (20). We report the results in Table 7. The magnitudes of the coefficients are smaller, but the signs and statistical significance are quite similar to our original results reported in Table 3.

5 Conclusion

Theoretically, we predicted that the quality slopes would increase in tariffs on imports from MICs and decrease in tariffs on imports from HICs, whereas the magnitude of these effects might decrease with technology diffusion. Empirically, we confirmed these predictions by regressing the estimated quality slopes on the U.S. tariffs on imports from MICs and HICs and their interaction terms with the technological diffusion proxies.

Intuitively, we view the expenditure pattern as an equilibrium outcome. As such, it is determined not only by preferences but also by the supply side. Instead of relying only on the elasticities of substitution, we emphasize the importance of the cost elasticity of quality. This allows for variation in the good-specific quality slopes over time solely due to variation in tariffs, while keeping both the preferences and available technologies constant over time.[33]

[33]If the effect of the supply side on quality slopes is muted, as in Bils and Klenow (2001), one must rely on the year-to-year changes in preferences to explain the inter-temporal variation in the quality slope of a given good.

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6 Appendix A

Proof of Lemma 1.

From the equilibrium condition for households purchasing northern goods (see equation (11)), for any given income I, a higher tariff on northern goods $\tau'_N > \tau_N$ will decrease the equilibrium consumption of both the numeraire and quality. Thus, for a household with an intermediate income level I_d and equilibrium quality z^+, both the consumption of the numeraire and quality of the differentiated good will decrease as well. This change will not affect the utility from consuming the southern-produced quality, and thus, a household with an intermediate income level I_d will strictly prefer southern quality z^- to the new equilibrium northern quality (which will be lower than z^+). As a result, the new intermediate income level, at which a household is indifferent between buying southern and northern quality, I'_d, will be higher than the original I_d. Thus, the share of consumers buying the southern quality will increase: $F\left(I'_d(\tau'_N)\right) > F\left(I_d(\tau_N)\right)$.

Similarly, a higher tariff on southern goods, $\tau'_S > \tau_S$, will decrease the southern-produced equilibrium quality for a household with income I_d, while leaving northern-produced equilibrium quality for the same household unchanged. Thus, a household with income I_d will strictly prefer the northern-produced quality to the southern-produced quality. Consequently, the new income level, at which, in equilibrium, a household is indifferent between southern- and northern-produced qualities, $\widetilde{I}(\tau_S')$, is lower than the original I_d. As a result, the share of households buying the southern quality will decrease: $F\left(\widetilde{I}(\tau_S')\right) < F\left(I_d(\tau_S)\right).$ ■

Proof of Proposition 2

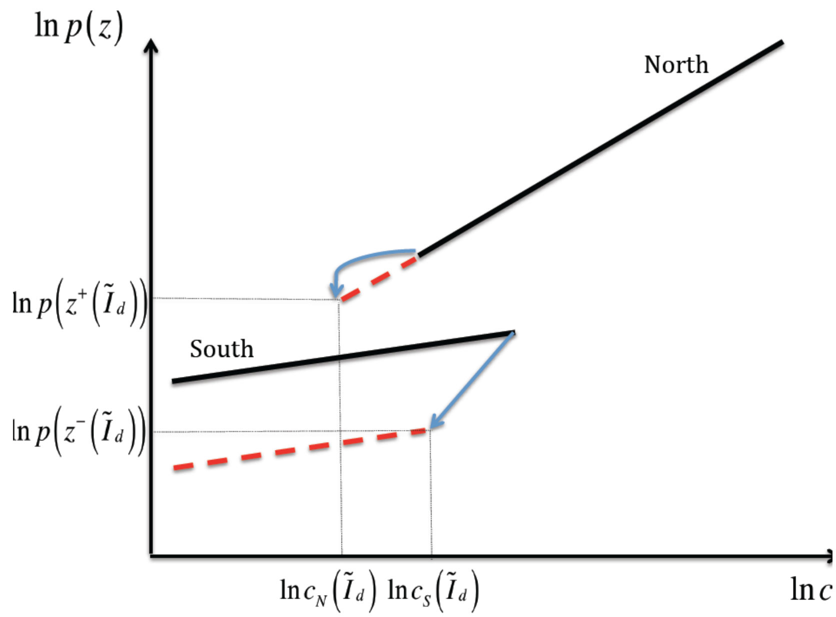

Figure 5: The Effect of a Higher Southern Tariff.

First, note that the quality slopes are not affected by tariffs (see equation (13)). For the case of a higher southern tariff τ_S, this point is illustrated by Figure 5. From Lemma 1, a higher southern tariff will decrease the share of Home households buying southern goods, which will automatically increase the share of households buying northern goods (these shifts are illustrated by the two arrows in Figure 5). Since the northern quality slope is steeper, an increase in the segment of households buying the northern quality will increase the average quality slope defined by equation (14).

Similarly, a higher τ_N will increase the share of households buying the southern-produced quality, and thus will decrease the weighted-average quality slope. ■

Proof of Proposition 3

First, we will show that the average quality slope is steeper with technological diffusion than without it. Second, we will show that the technology diffusion will either decrease or not affect the absolute magnitude of the tariff's effect on the average quality slope. The percentage change in the slope is given by the absolute change in slope over the initial slope. Since the magnitude of the absolute change is either the same or smaller, while the initial slope is larger, the ratio measuring the sensitivity of the quality slope to changes in tariffs will always be smaller in the presence of technological diffusion.

1. To show that the slope is larger under technology diffusion, we need to compare the magnitudes of equations (15) and (14). If the extent of the technology diffusion is insufficient for replacing the southern technology for the entire original southern quality segment (i.e., $z_T < z^-(I_d)$), the average slope under technology diffusion is given by the first line of equation (15). This slope is larger than the average slope without technology diffusion defined by equation (14), since a larger weight is assigned to the larger northern slope $\frac{\gamma_N}{\sigma(1/\varepsilon+\gamma_N-1)}$. That is, in addition to the original northern-produced quality segment, the northern slope will extend to the quality segment produced by South with diffused technology with the corresponding weight $F(I_T)$. If, on the other hand, the diffused technology will entirely replace the southern technology, the slope under technology diffusion will be even larger, since it will be ~~a~~ equal to the larger northern slope $\frac{\gamma_N}{\sigma(1/\varepsilon+\gamma_N-1)}$.

2. The share of households affected by the tariff change under technology diffusion will be either the same or smaller than the share of households affected by the same tariff change under no technology diffusion. It will be the same if the tariff change does not eliminate completely the southern-produced quality segment. That is, the highest quality produced using diffused technology z_T will be sufficiently far from the highest quality produced under the original southern technology $z^-(I_d)$, and thus changes caused by the tariff change will be insufficient for completely eliminating the share of households buying the quality produced under the original southern technology. If, on the other hand, a change in tariff will completely eliminate the share of households buying the quality produced under the original southern technology, the absolute effect of tariff on the average quality slope will be even smaller under technology diffusion than under no technology diffusion.

Table 5: The Effect of Quality Slopes on Unit Price Inflation

All goods	(1)	(2)	(3)	(4)	(5)
Quality Slope	0.07***			0.07***	
	(0.01)			(0.01)	
Fitted Quality Slope		0.27***			0.27***
		(0.09)			(0.10)
Change in log of tariff on High-Income Countries			-0.12	-0.09	-0.04
			(0.12)	(0.11)	(0.12)
Change in log of tariff on Middle-Income Countries			0.07	0.07	-0.01
			(0.08)	(0.07)	(0.08)
Constant	-0.01	0.05***	0.05***	-0.01	0.05***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
Adj. R-squared	0.07	0.02	0.02	0.07	0.02
No. Obs.	2131	2131	2131	2131	2131
Durable goods					
Quality Slope	0.07***			0.07***	
	(0.02)			(0.02)	
Fitted Quality Slope		0.16*			0.17*
		(0.10)			(0.10)
Change in log of tariff on High-Income Countries			-0.04	0.02	0.07
			(0.62)	(0.54)	(0.61)
Change in log of tariff on Middle-Income Countries			-0.08	-0.18	-0.18
			(0.18)	(0.19)	(0.18)
Constant	-0.01	0.05***	0.05***	-0.01	0.05***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
Adj. R-squared	0.09	0.03	0.02	0.09	0.02
No. Obs.	1015	1015	1015	1015	1015
Apparel, Footwear, and Textiles					
Quality Slope	0.06***			0.06***	
	(0.02)			(0.02)	
Fitted Quality Slope		0.53***			0.53***
		(0.14)			(0.13)
Change in log of tariff on High-Income Countries			-0.13	-0.09	0.02
			(0.12)	(0.11)	(0.11)
Change in log of tariff on Middle-Income Countries			0.12	0.11	-0.01
			(0.09)	(0.07)	(0.08)
Constant	-0.02*	0.02***	0.02***	-0.02*	0.02***
	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
Adj. R-squared	0.04	0.02	0.00	0.03	0.01
No. Obs.	1116	1116	1116	1116	1116

Notes: 1. Unit price inflation defined by averaging the log first difference of unit prices across households. 2. Regressions include product fixed effects. 3. Regressions including the quality slope estimates are weighted by the inverse of the standard errors of the quality slope estimates. 4. The fitted quality slope is the fitted value of the quality slope from the second stage regressions using only tariffs as explanatory variables. 5. Standard errors are clustered by products, significance * .10 ** .05 *** .01.

Table 6: The Effect of Tariffs on the U.S. Quality Slopes (Lagged Imports and FDI in the MICs)

X is One-Lag Imports of Manufactures (perc. of GDP) into Middle-Income Countries in specification (2) and (3)
X is One-Lag of FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5)

All goods	(1)	(2)	(3)	(4)	(5)
Log of tariff on High-Income Countries	-0.68***	-0.68***	-0.74***	-0.72***	-0.76***
	(0.16)	(0.16)	(0.17)	(0.16)	(0.17)
Log of tariff on Middle-Income Countries	0.79***	0.79***	1.35***	0.76***	0.97***
	(0.14)	(0.14)	(0.30)	(0.14)	(0.18)
X		-0.00	0.00	0.01**	0.02***
		(0.00)	(0.00)	(0.00)	(0.01)
Log of tariff on Middle-Income Countries * X			-0.03**		-0.10*
			(0.01)		(0.05)
Constant	0.70***	0.71***	0.68***	0.68***	0.67***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
Adj. R-squared	0.71	0.71	0.72	0.72	0.72
No. Obs.	2252	2252	2252	2252	2252
Durable goods					
Log of tariff on High-Income Countries	-2.49***	-2.22**	-1.89**	-2.51***	-2.30***
	(0.81)	(0.87)	(0.88)	(0.81)	(0.82)
Log of tariff on Middle-Income Countries	1.40***	1.34**	2.68***	1.37**	1.64***
	(0.54)	(0.54)	(0.66)	(0.54)	(0.51)
X		-0.00	-0.00	0.01	0.01
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			-0.09**		-0.20
			(0.04)		(0.13)
Constant	0.73***	0.73***	0.70***	0.72***	0.70***
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Adj. R-squared	0.66	0.66	0.66	0.66	0.66
No. Obs.	1074	1074	1074	1074	1074
Apparel,Footwear, and Textiles					
Log of tariff on High-Income Countries	-0.56***	-0.52***	-0.49***	-0.60***	-0.52***
	(0.16)	(0.16)	(0.17)	(0.16)	(0.16)
Log of tariff on Middle-Income Countries	0.46***	0.43***	-0.09	0.45***	-0.11
	(0.14)	(0.14)	(0.43)	(0.14)	(0.24)
X		0.00**	0.00	0.01**	-0.01
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			0.02		0.22***
			(0.02)		(0.07)
Constant	0.72***	0.70***	0.75***	0.72***	0.78***
	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)
Adj. R-squared	0.76	0.76	0.76	0.76	0.76
No. Obs.	1178	1178	1178	1178	1178

Notes:
1.Tariff rates are trade-weighted average of ad-valorem tariff rates, where weights are the import share from each country.
2.Exporters are classified in HICs and MICs using the World Bank classification.
3.Regressions are weighted by the inverse of the standard errors of QEC estimates.
4.Year and product fixed effects in all regressions.
5.Robust standard errors, significance * .10 ** .05 *** .01.

Table 7: The Effect of Tariffs on the U.S. Quality Slopes (Excluding China and Mexico)

Sample of exporters excludes China and Mexico
X is Imports of Manufactures (percent of GDP) into Middle-Income Countries in specification (2) and (3)
X is FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5)

All goods	(1)	(2)	(3)	(4)	(5)
Log of tariff on High-Income Countries	-0.44***	-0.43***	-0.46***	-0.45***	-0.47***
	(0.16)	(0.16)	(0.16)	(0.16)	(0.16)
Log of tariff on Middle-Income Countries	0.43***	0.39***	0.83***	0.44***	0.50***
	(0.14)	(0.15)	(0.28)	(0.14)	(0.18)
X		0.00*	0.00***	-0.01	-0.00
		(0.00)	(0.00)	(0.00)	(0.00)
Log of tariff on Middle-Income Countries * X			-0.02**		-0.02
			(0.01)		(0.05)
Constant	0.72***	0.69***	0.66***	0.73***	0.72***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
Adj. R-squared	0.71	0.71	0.71	0.71	0.71
No. Obs.	2239	2239	2239	2239	2239
Durable goods					
Log of tariff on High-Income Countries	-1.69**	-1.71**	-1.51*	-1.58**	-1.63**
	(0.77)	(0.77)	(0.77)	(0.78)	(0.76)
Log of tariff on Middle-Income Countries	0.12	0.12	0.76	0.14	1.13***
	(0.32)	(0.32)	(0.58)	(0.32)	(0.44)
X		0.00	0.00	-0.00	0.00
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			-0.03*		-0.31***
			(0.42)		(0.13)
Constant	0.74***	0.73***	0.71***	0.74***	0.73***
	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)
Adj. R-squared	0.66	0.66	0.66	0.66	0.66
No. Obs.	1061	1061	1061	1061	1061
Apparel, Footwear, and Textiles					
Log of tariff on High-Income Countries	-0.43***	-0.39**	-0.38**	-0.43***	-0.30*
	(0.15)	(0.16)	(0.16)	(0.15)	(0.16)
Log of tariff on Middle-Income Countries	0.24*	0.16	-0.34	0.24*	-0.27
	(0.14)	(0.15)	(0.37)	(0.14)	(0.21)
X		0.00**	0.00	0.00	-0.01**
		(0.00)	(0.00)	(0.00)	(0.01)
Log of tariff on Middle-Income Countries * X			0.02		0.19***
			(0.01)		(0.05)
Constant	0.73***	0.73***	0.78***	0.73***	0.78***
	(0.07)	(0.07)	(0.08)	(0.07)	(0.07)
Adj. R-squared	0.75	0.76	0.76	0.75	0.76
No. Obs.	1178	1178	1178	1178	1178

Notes:
1.Tariff rates are trade-weighted average of ad-valorem tariff rates, where weights are the import share from each country.
2.Exporters are classified in HICs and MICs using the World Bank classification.
3.Regressions are weighted by the inverse of the standard errors of QEC estimates.
4.Year and product fixed effects in all regressions.
5.Robust standard errors, significance * .10 ** .05 *** .01.

Table 8: The Effect of Tariffs on the U.S. Quality Slopes (with Simple Mean Tariffs)

Tariff is defined as simple-mean ad-valorem tariff
X is Imports of Manufactures (perc. of GDP) into Middle-Income Countries in specification (2) and (3)
X is FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5)

All goods	(1)	(2)	(3)	(4)	5)
Log of tariff on High-Income Countries	-1.63***	-1.61***	-1.57***	-1.67***	-1.49***
	(0.32)	(0.33)	(0.33)	(0.32)	(0.33)
Log of tariff on Middle-Income Countries	0.34**	0.34**	0.43	0.35**	0.46**
	(0.17)	(0.17)	(0.27)	(0.17)	(0.18)
X		-0.00	-0.00	0.021**	0.02***
		(0.00)	(0.00)	(0.01)	(0.02)
Log of tariff on Middle-Income Countries * X			-0.01		-0.11**
			(0.01)		(0.05)
Constant	0.76***	0.76***	0.76***	0.74***	0.71***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)
Adj. R-squared	0.71	0.71	0.71	0.72	0.72
No. Obs.	2252	2252	2252	2252	2252
Durable goods					
Log of tariff on High-Income Countries	-2.40***	-2.19***	-1.52**	-2.45***	-2.08***
	(0.63)	(0.65)	(0.64)	(0.63)	(0.62)
Log of tariff on Middle-Income Countries	0.68***	0.64**	2.74***	0.68***	1.29***
	(0.26)	(0.26)	(0.79)	(0.26)	(0.35)
X		-0.00*	-0.00	0.01	0.02**
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			-0.13***		-0.42**
			(0.05)		(0.17)
Constant	0.74***	0.76***	0.69***	0.73***	0.69***
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)
Adj. R-squared	0.66	0.66	0.66	0.66	0.66
No. Obs.	1074	1074	1074	1074	1074
Apparel, Footwear, and Textiles					
Log of tariff on High-Income Countries	-0.47	-0.59	-0.66*	-0.50	-0.64
	(0.39)	(0.39)	(0.39)	(0.39)	(0.40)
Log of tariff on Middle-Income Countries	-0.48*	-0.55**	-1.71***	-0.49*	-0.87***
	(0.25)	(0.25)	(0.46)	(0.25)	(0.28)
X		0.00***	-0.01*	0.01	-0.02
		(0.00)	(0.00)	(0.01)	(0.01)
Log of tariff on Middle-Income Countries * X			0.07***		0.21**
			(0.02)		(0.09)
Constant	0.81***	0.80***	0.76***	0.81***	0.87***
	(0.08)	(0.08)	(0.07)	(0.08)	(0.08)
Adj. R-squared	0.75	0.76	0.76	0.75	0.76
No. Obs.	1178	1178	1178	1178	1178

Notes:
1.Tariff rates are simple average of ad-valorem tariff rates, where weights are the import share from each country.
2.Exporters are classified in HICs and MICs using the World Bank classification.
3.Regressions are weighted by the inverse of the standard errors of QEC estimates.
4.Year and product fixed effects in all regressions.
5.Robust standard errors, significance * .10 ** .05 *** .01.