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Abstract

We provide theoretical predictions and empirical evidence for how changes in import tariffs affect the U.S. price dispersion (between rich and poor) of durable goods between 1989 and 2007. In a model with non-homothetic preferences and trade in vertically differentiated products, we predict that tariff cuts on imports from developed countries increase the price dispersion while tariff cuts on imports from developing countries decrease it. We confirm this novel prediction empirically and find that the price dispersion predicted by the tariffs on imports from the OECD and non-OECD countries closely traces the rich-to-poor price dispersion between 1989 and 2007.

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1 Introduction

During the past decades, the study of the effects of trade policy on the increasing U.S. income inequality has been an important topic for many researchers and political leaders. A vast body of research has shown theoretically and confirmed empirically the effects of international trade and trade policy on the distribution of nominal income through Stolper-Samuelson effect\(^1\). However, since richer consumers buy more expensive, presumably higher quality, varieties of goods than poorer consumers\(^2\), and many of those varieties are imported, trade policy has an additional effect on the real income inequality—through the price dispersion between rich and poor. In particular, lowering tariffs on imports from developing and developed countries may have an asymmetric effect on prices of low- and high-quality segments, consumed, respectively, by poorer and richer households. This channel got surprisingly little attention in the empirical trade literature\(^3\) even though there is an extensive research (starting with Linder \citeyear*{1961}) showing that quality differentiation is increasingly important for determining international trade patterns\(^4\) and that richer countries export and import more expensive, higher quality goods\(^5\).

We fill this gap by providing theoretical predictions and empirical evidence for how changes in tariffs affect the U.S. price dispersion between rich and poor households from 1989 to 2007. The non-homothetic consumption pattern in our model is explained by a combination of both demand and supply parameters from a perspective of a country which imports higher quality varieties from developed countries—demanded by rich households—and lower-quality varieties from developing countries—demanded by poor households. Lowering

\(^{1}\) Stolper and Samuelson \citeyear*{1941}, see Goldberg and Pavcnik \citeyear{2007, 2016} for literature reviews.
\(^{2}\) Bils and Klenow \citeyear*{2001} showed this result for durable goods while Broda and Romalis \citeyear*{2009} for grocery items in the U.S. consumption patterns.
\(^{3}\) The notable exceptions are Broda and Romalis \citeyear*{2009}; Faigelbaum and Khandelwal \citeyear*{2016}; Faber \citeyear*{2014}.
\(^{4}\) Hummels and Klenow \citeyear{2005}; Fieler \citeyear{2011} showed that the fit between theoretical predictions and international trade data is much better if models include quality differentiation and non-homothetic preferences.
\(^{5}\) See, for example, Schott \citeyear*{2004}; Hallak \citeyear*{2006}; Hummels and Klenow \citeyear*{2005}; Feenstra and Romalis \citeyear*{2014}.
tariffs on higher-quality varieties induces rich households to buy even more expensive varieties (due to substitution effect) and thus increases the price dispersion. Lowering tariffs on the lower-quality varieties, on the contrary, decreases the price dispersion, since it encourages poor households to upgrade their quality choices while leaving rich households unaffected. Empirically, we find that the U.S. price dispersion of durable goods indeed decreases with tariffs on imports from developed OECD countries and increases with tariffs on imports from developing non-OECD countries, which is a novel result of our paper. Furthermore, the price dispersion predicted by the tariffs on imports from the OECD and non-OECD countries closely traces the rich-to-poor price dispersion between 1989 and 2007.\footnote{For example, we find that the price dispersion for the median good between the 90th and 10th percentile of the households by income has increased from 2.4 to 2.8 between 1989 and 2007, while the corresponding price dispersion predicted by the variation in tariffs rose from 2.35 to 2.75 during the same period.}

Theoretically, we build on \cite{Bils2001} and employ a model with a homogenous non-durable numeraire and many quality-differentiated durable goods. The key feature of our model is that on the production side, motivated by previous research, we allow for non-unitary product-specific cost elasticity of quality.\footnote{\cite{Bils2001} simplified the production side of the model by assuming that all quality-differentiated goods face a constant-to-scale production function of quality with the unity cost elasticity of quality. In a different context, the importance of the cost elasticity of quality was previously emphasized by \cite{Baldwin2011}, who showed that in a heterogeneous-firm model, the sorting of firms via quality versus productivity is determined by the magnitude of the cost elasticity of quality. Furthermore, \cite{FeenstraRomalis2014} structurally estimated the production function of quality and found that the cost elasticity of quality is indeed non-unitary and varies across goods.}

Following \cite{Bils2001}, we derive a “quality slope” (QS) for each quality-differentiated good—defined as the extent to which richer households pay more for a given quality-differentiated good with respect to their expenditures on the homogenous numeraire—and link it to the price dispersion between poor and rich households. In particular, quality slope can be interpreted as a product-specific parameter which allows us to calculate rich-to-poor price dispersion using the rich-to-poor ratio of expenditures on the numeraire.\footnote{For example, if QS for jewelry is 1.4, the price dispersion of jewelry for two households with one of them spending twice more on the numeraire, everything else same, can be calculated as $2^{1.4} = 2.64$.}
hogeneous households is defined not only by preferences but also by the production function of quality. Namely, quality slope and price dispersion of a given product decrease in its cost elasticity of quality.

In autarky, if preferences and technology are stable over time, so are the quality slopes. However, if a country imports varieties of a quality-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, the average quality slope, and thus the price dispersion.

We explore this intuition by allowing for technological differences between two countries, North and South, each of which exports the quality-differentiated durable goods 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 households buying northern varieties generate a steeper quality slope than the purchases made by households buying southern varieties, whereas the (weighted) average quality slope depends on the shares of northern and southern varieties in Home’s import mix. Consequently, the tariffs on northern varieties will decrease both the average quality slope and the resulting rich-to-poor price dispersion as they reduce the share of northern varieties in Home. The tariffs on southern varieties will have the opposite effect. Technological diffusion from North to South is likely to decrease the magnitudes of these effects.

Empirically, we 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. In particular, we 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 57 consumer durable goods. We first confirm that our estimates of quality slopes
decrease in the cost elasticity of quality estimated by Feenstra and Romalis (2014)⁹.

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 3.3%, while a 1% reduction in the tariff on goods from middle-income countries decreases it by 1%. When we control for potential channels of quality upgrading of exports from middle-income countries, the latter effect increases almost four-fold, from 1% to 3.7%.

Last, we quantify the effects of changes in tariffs on price dispersion through quality slopes. Using quality slopes for this purpose allows us to control for heterogeneity in household demographics and to identify and estimate the effect of non-durable expenditures on household prices.¹⁰ Changes in tariffs increase the rich-to-poor price dispersion, on average, by 9% from 1989 to 2007, which explain 31% of the average increase in the rich-to-poor price dispersion in the CE data over the same period. Our results, highlight that higher tariffs on lower-quality varieties originating from middle-income countries increases the rich-to-poor price dispersion.

Our paper contributes to several literatures. First, we contribute to the extensive research on the effects of trade and trade policy on income inequality. Goldberg and Pavcnik (2007, 2016) provide an extensive review of this literature.¹¹ Importantly, this literature focuses

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⁹Feenstra and Romalis (2014) were the first to estimate product-specific cost elasticities of quality using a multi-country dataset. Previous estimates of cost elasticities of quality were obtained from country-specific datasets: Crozet et al. (2012) estimated these elasticities for French champagnes; Nguyen (2009) estimated them for Danish exports.

¹⁰As we discuss in Subsection 2.2, expenditures on consumption is considered to be a better measure of well-being than income (see, for example, Goldberg and Pavcnik, 2007).

¹¹See also Verhoogen (2008), Topalova (2010), Brambilla et al. (2012).
mainly on the nominal wage inequality across skill or income groups, while our paper explores how trade policy affects rich-to-poor price dispersion—an important component in calculating real income inequality.\footnote{Identifying both changes in nominal income and changes in relative prices paid by rich and poor households is necessary when calculating real income inequality. For example, Moretti (2013) shows that real wage differences between skilled and unskilled workers are much smaller when we consider the geographical location and cost of living of these groups.}

Second, our paper is more closely related to a growing literature which focuses directly on the effects of trade and trade policy on rich-to-poor price dispersion. Many of these studies use microdata\footnote{One notable exception is Fajgelbaum and Khandelwal (2016).} on household consumption to examine the distributional effects of trade liberalization and show that trade policy has a different impact on the prices that rich and poor households pay. Porto (2006) combines scheduled Argentine tariff changes under Mercosur with household expenditure shares across seven consumption sectors to show that, since households pay different prices for traded and non-traded goods, Argentine tariff removals benefitted the poor over the rich. Fajgelbaum and Khandelwal (2016) uses country-level trade and production for 40 countries and 35 sectors, and they also find that trade liberalization favors poor households because they spend a significant share of their budget on traded goods for which prices decrease. Both of these studies show that the decline in the relative price of traded goods as result of trade liberalization has important distributional effects since poor and rich households differ in their consumption shares of traded goods. In contrast to these studies, our paper focuses on the effect of tariff cuts on rich-to-poor price dispersion within a narrowly defined vertically-differentiated product.

Using Mexican microdata, Faber (2014) shows that better access to imported intermediates from the U.S. due to NAFTA decreased the relative price of higher quality goods in Mexico, increasing the real income inequality in urban Mexico. To compare the effect of NAFTA on rich and poor households, Faber (2014) kept the reference utility level for each household type constant over time and focused on the changes in prices of the same baskets. 

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of goods for each household type. We complement this research by examining the individual effects of tariffs on imports from developed and developing countries on the U.S. rich-to-poor price dispersion. Importantly, we focus on the actual choices of the rich and poor households, not restricting them to consume the same baskets over time. Thus, even though lower tariffs on imports from developed countries decrease the prices of high-quality goods, lowering tariffs may also induce rich households to substitute for even higher quality, which would increase the rich-to-poor price dispersion.

Broda and Romalis (2009) analyze the link between non-durable consumer good imports from China and household inflation differences using homescanner data in the US. Our findings complement those of Broda and Romalis (2009) by showing that U.S. price dispersion increases not only for grocery items but also for durable goods.

Third, we also contribute to an extensive literature on quality differentiation and international trade. One of the important findings of this research is that richer countries import more expensive goods (see, e.g., Hallak 2006; Hummels and Klenow 2005). We corroborate the existing evidence that richer households buy more expensive varieties of products and that both within-country income distribution and level of development of the country-of-origin are important when evaluating the impact of trade policy on domestic prices. This result is in line with findings of Choi et al. (2009) who demonstrated a connection between the within-country income distribution and the distribution of import prices. The novelty of our paper is in providing a direct link between the rich-to-poor price dispersion and tariff variation.

Finally, we add 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 2016) literatures on how non-homothetic preferences and the within-country income heterogeneity affect patterns of,

\[\text{See Markusen (2013) and Feenstra and Romalis (2014) for the reviews of the recent literature.}\]

\[\text{See, e.g., Bils and Klenow (2001); Handbury (2013).}\]
and gains from, international trade. We complement these literatures by showing that international trade, in turn, affects the households’ expenditure patterns. We emphasize that equilibrium consumption patterns and their degree of non-homotheticity are an equilibrium result and as such depend on both demand and supply side parameters. In particular, in addition to the preferences for quality, the technology of quality production matters, and if this technology varies across countries, trade and trade barriers affect the relative expenditures on quality-differentiated goods. In addition, our empirical results provide indirect evidence supporting the underlying assumption of many of these models that developing countries have a higher cost elasticity of quality than developed countries.

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 strategy, and results. Section 5 concludes the paper.

2 Theoretical Framework

We want to show that the price dispersion of the quality-differentiated goods depends not only on the preferences for quality, but also on the cost of quality upgrading since a consumer’s choice is based on both the marginal benefit and marginal cost of quality. To this goal, we use a modified version of Bils and Klenow (2001) model and show that the price dispersion of quality-differentiated durable goods decreases in the cost elasticity of quality.\footnote{In their original model, Bils and Klenow (2001) assume a constant returns to scale production function of quality with the corresponding that cost elasticity of quality being one for all quality-differentiated goods. We relax this assumption and allow for a non-unity cost elasticity of quality.}

We further extend the autarky model to a three-country (Home, North, and South) trade model in which North has a lower cost elasticity of quality than South. Using tariffs as demand shifter, we predict that the Home’s price dispersion between richer and poorer households decreases in tariffs on northern durables and increases in tariffs on southern

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durables. Technological diffusion is likely to reduce the magnitudes of these effects.

2.1 Autarky

Household $h = 1, 2, ..., H$ maximizes utility defined over the numeraire composite $c_h$ and the quality levels $z_{hg}$ of durable indivisible goods $g = 1, 2, ..., G$:

$$u_h = \frac{c_h^{1-1/\sigma}}{1-1/\sigma} + \sum_{g=1}^{G} \tilde{v}_{hg} \frac{z_{hg}^{1-1/\varepsilon_g}}{1-1/\varepsilon_g} \quad \sigma, \varepsilon_g > 1, \quad \tilde{v}_{hg} \geq 0,$$

(1)

where $\sigma$ and $\varepsilon_g$ are the preference parameters determining the curvature of utility for the goods, and $\tilde{v}_{hg} \in \{0, 1\}$ is the preference parameter of household $h$ for good $g$. If $\tilde{v}_{hg} = 0$, the household will choose not to own good $g$.

We normalize the price of the numeraire to one, which allows us to write the budget constraint as

$$c_h + \sum_{g=1}^{G} p_{hg}(z_{hg}) \leq I_h,$$

(2)

where $p_{hg}(z_{hg})$ is the price paid by household $h$ for quality $z_{hg}$ of good $g$, and $I_h$ is $h$’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 $z_g$ is given by $C(z_g) = \alpha_g z_g^{\gamma_g}$, where $\gamma_g > 1$ is the cost elasticity of quality (of product $g$) and $\alpha_g > 0$.

Firms behave competitively, and thus the price of a quality-differentiated good $g$ with quality $z_g$ is equal to its production cost:

$$p(z_g) = \alpha_g z_g^{\gamma_g},$$

(3)

This allows us to accommodate for the possibility that households do not necessarily buy all types of durable goods.

The corresponding production function of quality is given by $z_g = (1/\alpha_g)^{1/\gamma_g}$. Feenstra and Romalis (2014) used the same functional form of the production function of quality, where $0 < \frac{1}{\gamma_g} < 1$ reflects diminishing returns to quality.
from which the marginal cost of quality is \( \frac{dp(z_g)}{dz_g} = \alpha_g \gamma z_g^{\gamma - 1}. \)

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 \( z_{hg} \) is equal to the price of the numeraire over the marginal cost of quality \( z_{hg} \):

\[
\frac{c_h^{-1/\sigma}}{\tilde{v}_{hg} z_{hg}^{-1/\varepsilon_g}} = \frac{1}{\alpha_g \gamma z_g^{\gamma - 1}}.
\] (4)

Using equations (3) and (4), we substitute for \( p_{hg}(z_{hg}) \) with the numeraire in the budget constraint (2) to derive the implicit solution to the utility maximization problem:

\[
\begin{align*}
  z_{hg} &= \left( \tilde{v}_{hg} c_h^{1/\sigma} \right)^{1/(1/\varepsilon_g + \gamma - 1)} \quad \forall g \\
  c_h + \sum_{g=1}^{G} \alpha_g \left( \frac{\tilde{v}_{hg} c_h}{\alpha_g \gamma_g} \right)^{\gamma_g/(1/\varepsilon_g + \gamma_g - 1)} &= I_h
\end{align*}
\] (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. 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 \( \theta_{hg} \):

\[
\theta_{hg} \equiv \frac{\% \Delta p_{hg}}{\% \Delta I_h} \bigg/ \frac{\% \Delta c_h}{\% \Delta I_h} = \frac{\% \Delta p_{hg}}{\% \Delta c_h}.
\]
In our model, the quality slope can be derived from equations \(3\) and \(4\) as:

\[
\theta_{hg} = \frac{\partial \ln p_{hg}}{\partial \ln c_h} = \frac{\gamma_g}{\sigma (1/\varepsilon_g + \gamma_g - 1)}.
\] (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: \(\theta_{hg} = \theta_g \forall h, g\).

**Lemma 1** Bils and Klenow (2001): the smaller is the curvature in preferences with respect to the quality \(z_g\) (i.e., the higher is \(\varepsilon_g\)), the steeper is the quality slope \(\theta_g\) \(\left(\frac{\partial \theta_g}{\partial \varepsilon_g} > 0\right)\).

**Proof.** It follows directly from equation (6).  ■

As indicated above, this result follows directly from Bils and Klenow (2001). Next we present a new result of our model, which emphasizes the importance of the cost elasticity of quality.

**Lemma 2** The more costly is the quality upgrading of good \(g\) (i.e., the higher is \(\gamma_g\)), the flatter is the quality slope \(\theta_g\) \(\left(\frac{\partial \theta_g}{\partial \gamma_g} < 0\right)\).

**Proof.** It follows directly from equation (6).  ■

**Proposition 1** Ceteris paribus, an increase in the quality slope of good \(g\) results in a higher price dispersion of good \(g\) between households with higher and lower consumption levels of the numeraire.

**Proof.** See Appendix.  ■

This result is essential for the analysis of the effect of trade policy on the price dispersion in the model with trade.
2.2 Model with Trade

In this section, we introduce international trade and allow technologies to differ across countries. We set the model from Home’s perspective: Home imports quality-differentiated durable goods from two other countries, North and South (indexed by $N$ and $S$, respectively), and pays for them with the numeraire. For simplicity, we assume that Home has insufficient capacity to satisfy its demand for quality-differentiated goods. Thus, even for quality segments where Home has lower marginal cost than North and South those qualities are also imported and Home’s prices are determined by the prices of imports.\footnote{This assumption is consistent with the models of international trade under perfect competition and imports-as-market-discipline literature (see, for example, \textcite{Levinsohn,1993, Harrison,1994}).}

Preferences and the budget constraint for Home’s household $h$ remain the same as in the autarky model (see equations (1) and (2), respectively). 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.

The labor unit requirements for producing quality $z_g$ of good $g$ in North and South are given as follows:

\[ C_{gN}(z_g) = \alpha_{gN} z_g^{\gamma_{gN}} \quad C_{gS}(z_g) = \alpha_{gS} z_g^{\gamma_{gS}} \quad \gamma_{gS} > \gamma_{gN} > 1 \quad \alpha_{gN} > \alpha_{gS} > 0. \]  

Note that South has a lower unit cost multiplier ($\alpha_{gN} > \alpha_{gS}$), while North has a lower cost elasticity of quality ($\gamma_{gN} < \gamma_{gS}$). This cost structure implies that South possesses both absolute and comparative advantages in lower qualities, while North has them in higher qualities.

In each differentiated sector $g$, firms behave competitively, and the trade cost is given by the tariff expressed in iceberg form: $\tau_{ig} > 1$, $i \in \{N, S\}$. Thus, the delivered price at Home
is equal to the corresponding labor unit requirement times the iceberg trade cost:

\[ p_{gN}(z_g) = \alpha_{gN} z^{\gamma_{gN}} \tau_{gN} \quad \quad p_{gS}(z_g) = \alpha_{gS} z^{\gamma_{gS}} \tau_{gS}. \]  

(8)

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

\[ p(z_g) = \min\{\alpha_{gN} z^{\gamma_{gN}} \tau_{gN}, \alpha_{gS} z^{\gamma_{gS}} \tau_{gS}\}. \]  

(9)

Since South has a comparative advantage in lower quality products, while North has it in higher quality products, equation (9) represents the price profile in a competitive equilibrium. From equation (8), we can also find the quality level \( \overline{z}_g \), which is equally costly to produce when either northern or southern technologies are employed:

\[ \overline{z}_g = \left( \frac{\alpha_{gN} \tau_{gN}}{\alpha_{gS} \tau_{gS}} \right)^{1/(\gamma_{gS} - \gamma_{gN})}. \]

That is, the southern comparative advantage will be in qualities below \( \overline{z}_g \), while the northern comparative advantage will be in qualities above \( \overline{z}_g \).

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 \( z_g < \overline{z}_g \) and North will specialize in the high quality \( \overline{z}_g < z_g \) with \( z_g < z_g^+ \). Similar to Flam and Helpman (1987), there exists an income level \( I_{dg} \) allocated to the consumption of the numeraire and good \( g \) such that a household with positive preference parameter for \( g \) (\( \nu_{dg} = 1 \)) is indifferent between buying quality \( z_g^- \) from South and quality \( z_g^+ \) from North. In such a case, we assume that a household will always choose quality \( z_g^- \).\footnote{This will ensure a single equilibrium.}

If household \( h \) has a sufficiently high income, \( I_{hg} > I_{dg} \), it will choose from the qualities produced by North, and its utility-maximizing quality and corresponding price will be given
by:

\[ z_{hN} = \left( \frac{\bar{v}_{hN} \frac{1}{\sigma}}{\alpha_{gN} \gamma_{gN} \tau_{gN}} \right)^{\frac{1}{1/\varepsilon_{g} + \gamma_{gN} - 1}} \quad \nu(z_{hN}) = \alpha_{gN} \left( \frac{\bar{v}_{hN} \frac{1}{\sigma}}{\alpha_{gN} \gamma_{gN} \tau_{gN}} \right)^{\frac{\gamma_{gN}}{1/\varepsilon_{g} + \gamma_{gN} - 1}}. \]  

(10)

If, on the other hand, household \( h \) does not have a sufficiently high income, \( I_{h} < I_{d}, \) it will choose from the qualities produced by South, and their utility-maximizing quality and corresponding price will be given by:

\[ z_{hS} = \left( \frac{\bar{v}_{hS} \frac{1}{\sigma}}{\alpha_{gS} \tau_{gS} \gamma_{gS}} \right)^{1/(1/\varepsilon_{g} + \gamma_{gS} - 1)} \quad \nu(z_{hS}) = \alpha_{gS} \left( \frac{\bar{v}_{hS} \frac{1}{\sigma}}{\alpha_{gS} \gamma_{gS} \tau_{gS}} \right)^{\gamma_{gS}/(1/\varepsilon_{g} + \gamma_{gS} - 1)}. \]  

(11)

Note, that for a given expenditure on the numeraire, \( c_{h} \), a higher tariff on the imports from North corresponds to a lower price paid for the quality-differentiated good \( g \) imported from North (from eq. (10), since \( \frac{1}{\varepsilon_{g}} < 1 \)), while a higher tariff in imports from South corresponds to a lower price paid for the quality-differentiated good \( g \) imported from South (from eq. (11), since \( \frac{1}{\varepsilon_{g}} < 1 \)).

Similar to the autarky model, equations (8), (10), and (11) allow us to derive the quality slopes for the northern and southern-produced qualities:

\[
\begin{align*}
\theta_{gN} &= \frac{\partial \ln \nu(z_{hN})}{\partial \ln c_{h}} = \frac{\gamma_{gN}}{\sigma(1/\varepsilon_{g} + \gamma_{gN} - 1)}, \\
\theta_{gS} &= \frac{\partial \ln \nu(z_{hS})}{\partial \ln c_{h}} = \frac{\gamma_{gS}}{\sigma(1/\varepsilon_{g} + \gamma_{gS} - 1)}. 
\end{align*}
\]  

(12)

Figure 1 illustrates the above equilibrium. The northern quality slope is larger than the southern one, since the northern cost elasticity of quality is lower than the southern one: \( \gamma_{gN} < \gamma_{gS} \).

To derive testable predictions, we are interested in calculating 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 good \( g \) from South and North as \( F(I_{d}) \) and \( 1 - F(I_{d}) \), respectively,
where $F(I_{hg})$ denotes the cumulative distribution function of income allocated to good $g$ and the numeraire, $I_{hg}$. The weighted-average quality slope can then be defined as a weighted sum of $\theta_{gS}$ and $\theta_{gN}$:

$$\bar{\theta}_g \equiv F(I_{dg}) \frac{\gamma_{gS}}{\sigma(1/\varepsilon_g + \gamma_{gS} - 1)} + [1 - F(I_{dg})] \frac{\gamma_{gN}}{\sigma(1/\varepsilon_g + \gamma_{gN} - 1)}.$$ (13)

Next we will provide predictions on how tariffs affect the share of households buying southern goods, quality slopes, and price dispersion.\footnote{The proofs of Lemma 3 and Proposition 2 are provided in the Appendix.}

**Lemma 3** The share of households buying southern varieties of good $g$, $F(I_{dg})$, decreases in the Home’s tariff on southern varieties of good $g$ and increases in the tariff on northern varieties of good $g$.

Lemma 3 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 of good \( g \), \( \theta_g \), increases in the tariff on southern varieties of good \( g \) and decreases in the tariff on northern varieties of good \( g \).

Proposition 2 extends the intuition of Lemma 3 and shows that the average quality slope can be affected by import tariffs even if preferences and country-specific technologies are fixed.

Next, we will show that the price dispersion between rich and poor households is also affected by import tariffs. To this goal, we first define the price dispersion.

**Definition 1** Define a rich-to-poor price dispersion of good \( g \) as a ratio of prices

\[
\frac{p_g(\tau_g)}{p_g(c_g)}
\]

where \( p_g(\tau_g) \) and \( p_g(c_g) \) are the equilibrium prices paid for good \( g \) by households with sufficiently different expenditures on non-durable goods, \( \tau_g > c_g \), so that in equilibrium the household with \( \tau_g \) buys a northern-produced variety of \( g \), while the household with \( c_g \) buys a southern-produced variety of \( g \).

Note, that the price dispersion is defined based on the expenditures on the non-durable numeraire rather than in terms of income. In our model the household with the higher (lower) spending on the numeraire does not necessarily has the higher (lower) total expenditure, since each household has idiosyncratic preferences regarding whether to buy or not good \( g = 1, 2, ..., G \). In the data, however, we observe that the household expenditures on the non-durable goods are highly correlated with the total expenditure (the correlation coefficient is 0.91), which allows us to label households with high expenditures on non-durable as rich and with low expenditures on non-durables as poor. Importantly, previous research has identified consumption rather than income to be the more appropriate variable to capture the well-
being\(^{22}\) which provides an additional support for grouping the households based on their spending on non-durable consumption. Proposition\(^3\) provides testable predictions regarding the effect of import tariffs on the price dispersion.

**Proposition 3** The rich-to-poor price dispersion of good \(g\) increases in the tariff on the southern-produced varieties of good \(g\) and decreases in the tariff on the northern-produced varieties of good \(g\):

\[
\frac{\partial p_g(z_g)}{\partial \tau_{gS}} > 0; \quad \frac{\partial p_g(z_g)}{\partial \tau_{gN}} < 0.
\]

**Proof.** See Appendix. ■

### 2.3 The effect of Technological Diffusion

The strength and even the existence of the effect of trade policy on quality slopes depends on how different the northern and southern technologies are. The more similar the technologies are, the lesser is the effect of the trade policy\(^{23}\) Thus technological diffusion, which induces catching up of the southern technology with the northern one, is likely to decrease the effects of tariffs on quality slopes. To explore this intuition, we introduce technological diffusion in our model and then formalize the result in Proposition 4.

Let South be able to obtain northern elasticity of quality for a certain continuous quality segment of good \(g\), between the lowest produced quality \(z_g\) and certain intermediate quality \(z_{Tg}\), while keeping the other cost parameter, \(\alpha_{gS}\), unchanged. Since \(\alpha_{gS} < \alpha_{gN}\), South will have a comparative advantage in \([z_g, z_{Tg}]\), and the average quality slope, defined by equation

\(^{22}\)As summarized by Goldberg and Pavcnik (2007), (i) consumption allows to account for the inter-temporal shift of resources; (ii) reporting problems are less of an issue for consumption; and (iii) changes in expenditures on consumption take into account changes in prices.

\(^{23}\)In the extreme case, when technologies are identical, tariffs will have no effect on the quality slope.
([13]), can be redefined as follows:

\[
\hat{\theta}_{Tg} = \begin{cases} 
\text{Tech. diffusion} & \frac{F(I_{Tg}) \gamma_{gN}}{\sigma(1/\varepsilon_{g} + \gamma_{gN} - 1)} + \frac{[F(I_{dg}) - F(I_{Tg})] \gamma_{gS}}{\sigma(1/\varepsilon_{g} + \gamma_{gS} - 1)} + \frac{[1 - F(I_{dg})] \gamma_{gN}}{\sigma(1/\varepsilon_{g} + \gamma_{gN} - 1)} & \text{if } z_{Tg} < z^{-}(I_{dg}) \\
\text{southern tech.} & \frac{\gamma_{gN}}{\sigma(1/\varepsilon_{g} + \gamma_{gN} - 1)} & \text{if } z_{Tg} \geq z^{-}(I_{dg}) \\
\text{northern tech.} & \frac{\gamma_{gS}}{\sigma(1/\varepsilon_{g} + \gamma_{gS} - 1)} & \text{No southern tech.}
\end{cases}
\]  

(14)

where \( I_{Tg} \) denotes the income at which the household is indifferent between the qualities produced under the original and diffused technologies. Note that if \( z_{Tg} < z^{-}(I_{dg}) \), the segment \([z_{g}, z_{Tg}]\) is smaller than the original set of qualities produced by South, and the qualities in the segment \([z_{Tg}, z^{-}(I_{dg})]\) will still be produced with the southern cost elasticity of quality, \( \gamma_{gS} \). If, on the other hand, \( z_{Tg} > z^{-}(I_{dg}) \), all qualities will be produced with the northern cost elasticity of quality upgrading, \( \gamma_{gN} \).

**Proposition 4** For a given product, the technological diffusion from North to South decreases the relative effects of tariffs on the quality slope \( \left( \frac{\partial \hat{\theta}_{Tg}}{\partial \tau_{g_{i}}}, \frac{\tau_{g_{i}}}{\hat{\theta}_{Tg}} \right) < \left( \frac{\partial \hat{\theta}_{g}}{\partial \tau_{g_{i}}}, \frac{\tau_{g_{i}}}{\hat{\theta}_{g}} \right), \forall g, i \).

**Proof.** See Appendix A. \( \blacksquare \)

Having derived the main predictions of the model, in Section 3 we will estimate the year- and good-specific quality slopes. The estimated quality slopes are then used in Section 4 to verify the predictions of the model. In Section 4 we begin by exploring the effect of U.S. tariffs on goods originating from developed and developing countries on the quality slopes. Then, we will conduct back-of-envelope calculations to assess the impact of U.S. tariffs on price dispersion through changes in quality slopes.
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 two 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 estimate 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 allows 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.\(^{24}\)

3.1 Data and Descriptive Statistics

We use the 1988–2008 U.S. Household Expenditure Surveys\(^{25}\) to estimate the annual quality slopes for 57 household goods.\(^{26}\) The surveys contain information on the unit prices paid by households for each of the 57 goods consumed in our sample. The CE has a rotating sample of about 5,000 households\(^{27}\) 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. We also use data on nondurable expenditures\(^{28}\) and household demographics such as the U.S. regions (Northeast, Midwest, South, and West),

\(^{24}\)Since we use three-year moving average slopes, 21-year data span allows us to estimate 19 quality slopes, between 1989 and 2007.
\(^{25}\)http://www.bls.gov/cex/
\(^{26}\)While the CE dataset contains information on a larger set of goods, we restrict our sample to durable goods that households buy throughout the entire sample period. Following the classification of the National Income and Product Accounts, we identify 57 durable goods.
\(^{27}\)The list of the goods is available in Table 1 of the Online Appendix at http://mypage.iu.edu/~vlugovsk/online_appendix.pdf
\(^{28}\)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.
\(^{29}\)Following Bils and Klenow (2001), we (i) use nondurable expenditures as a proxy for permanent income, and (ii) exclude apparel, footwear, and textile goods from the nondurable expenditures.
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.  

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean</th>
<th>Median</th>
<th>St.Dev</th>
<th>90th/10th</th>
<th>No. obs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>17,450</td>
<td>15,595</td>
<td>9,738</td>
<td>3.92</td>
<td>2,494</td>
</tr>
<tr>
<td>1989</td>
<td>17,942</td>
<td>15,670</td>
<td>10,393</td>
<td>4.06</td>
<td>2,481</td>
</tr>
<tr>
<td>1990</td>
<td>17,471</td>
<td>15,235</td>
<td>10,067</td>
<td>4.02</td>
<td>2,557</td>
</tr>
<tr>
<td>1991</td>
<td>17,797</td>
<td>15,604</td>
<td>10,204</td>
<td>3.93</td>
<td>2,569</td>
</tr>
<tr>
<td>1992</td>
<td>17,131</td>
<td>14,981</td>
<td>9,860</td>
<td>3.94</td>
<td>2,568</td>
</tr>
<tr>
<td>1993</td>
<td>17,175</td>
<td>14,982</td>
<td>9,959</td>
<td>3.96</td>
<td>2,594</td>
</tr>
<tr>
<td>1994</td>
<td>17,341</td>
<td>15,419</td>
<td>10,082</td>
<td>3.97</td>
<td>2,534</td>
</tr>
<tr>
<td>1995</td>
<td>16,894</td>
<td>14,488</td>
<td>11,200</td>
<td>4.08</td>
<td>1,820</td>
</tr>
<tr>
<td>1996</td>
<td>18,000</td>
<td>15,631</td>
<td>10,389</td>
<td>3.69</td>
<td>1,730</td>
</tr>
<tr>
<td>1997</td>
<td>17,505</td>
<td>15,343</td>
<td>9,793</td>
<td>3.87</td>
<td>2,678</td>
</tr>
<tr>
<td>1998</td>
<td>17,391</td>
<td>15,466</td>
<td>9,681</td>
<td>3.99</td>
<td>2,636</td>
</tr>
<tr>
<td>1999</td>
<td>18,488</td>
<td>15,923</td>
<td>13,314</td>
<td>4.17</td>
<td>3,199</td>
</tr>
<tr>
<td>2000</td>
<td>18,055</td>
<td>15,752</td>
<td>10,429</td>
<td>3.97</td>
<td>3,552</td>
</tr>
<tr>
<td>2001</td>
<td>19,248</td>
<td>16,329</td>
<td>20,112</td>
<td>4.06</td>
<td>3,363</td>
</tr>
<tr>
<td>2002</td>
<td>19,282</td>
<td>16,649</td>
<td>11,572</td>
<td>4.05</td>
<td>3,603</td>
</tr>
<tr>
<td>2003</td>
<td>18,915</td>
<td>16,487</td>
<td>12,227</td>
<td>4.04</td>
<td>3,641</td>
</tr>
<tr>
<td>2004</td>
<td>17,717</td>
<td>17,085</td>
<td>15,361</td>
<td>4.25</td>
<td>2,531</td>
</tr>
<tr>
<td>2005</td>
<td>20,978</td>
<td>18,275</td>
<td>12,634</td>
<td>4.06</td>
<td>2,283</td>
</tr>
<tr>
<td>2006</td>
<td>20,694</td>
<td>17,746</td>
<td>12,685</td>
<td>4.23</td>
<td>3,174</td>
</tr>
<tr>
<td>2007</td>
<td>21,122</td>
<td>18,196</td>
<td>16,331</td>
<td>4.35</td>
<td>3,092</td>
</tr>
<tr>
<td>2008</td>
<td>21,328</td>
<td>18,554</td>
<td>12,934</td>
<td>3.96</td>
<td>3,063</td>
</tr>
</tbody>
</table>

Source: Household Expenditure Survey 1988-2008

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 considerable variation in annual nondurable expenditures across households. Furthermore, given that the median is on average 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 times. The magnitudes are similar for other years in our sample.  

While the variation in prices is often attributed to the variation in markups on the same goods, we believe that an important part of the rich-to-poor price distribution can be attributed to the fact that richer households consume more expensive higher quality consumer goods.

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

31 Price variation for each good in 1989 and 2007 is available in Table 1 of the Online Appendix at http://mypage.iu.edu/~vlugovsk/online_appendix.pdf
goods, since the magnitudes we observe are much larger than previously reported differences in prices of the same goods.\textsuperscript{32}

Importantly, price dispersion is not constant over time. As demonstrated by the left panel of Figure 2, for most of the goods, price dispersion increases between 1989 and 2007. The right panel of Figure 2 decomposes the price dispersion into the intertemporal changes in the lowest (i.e. 10th percentile) and highest prices (i.e. 90th percentile).\textsuperscript{33} The decomposition shows that the highest prices have increased for 36 goods (out of 57), while the lowest prices have decreased for 42 goods. The price dispersion has increased due to both of these factors for 18 goods, whereas both factors worked in the opposite (price compression) direction only for 3 goods.

Overall, these data are uniquely suited for an analysis of how the quality slopes and price dispersion of durable goods 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 several 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 the quality of the data because many academic researchers and policymakers have used them

\textsuperscript{32}For example, Kaplan and Menzoio (2015) using barcode data from the Kilts-Nielsen Consumer Panel reported that “a household at the 90th percentile of the price index distribution pays approximately 22\% more than a household at the 10th percentile.”

\textsuperscript{33}For graph readability, the figure shows data for only 53 out of the 57 goods in our sample. Cars, Musical Equipment, Office furniture and Playground equipment show a bigger change in lowest or highest prices.
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 $\theta_{gt}$ 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:

$$
\log p_{hgt} = \text{Const}_{gt} + \theta_{gt} \log c_{ht} + \sum_i \beta_i T_i H_{ht} + \epsilon_{htg},
$$

(15)
where, following Bils and Klenow (2001), our set of control variables, denoted by $\sum_i H_{ht}$, 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.\footnote{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’ preferences by incorporating some household characteristics.}

To correct for measurement errors in the households’ reported nondurable expenditures, we estimate the goods’ quality slopes by two-stage least squares (2SLS).\footnote{According to Bils and Klenow (2001), misreported nondurable expenditures might bias the estimates toward zero, and two-stage least squares estimation is necessary to correct the bias. They did find that the OLS estimates are slightly lower than the 2SLS estimates.} 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 the data from 1988, 1989, and 1990. In doing so, the estimation smooths 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.\footnote{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.}

The vast majority of the estimated quality slopes are positive and statistically significant at the 10% level or better, whereas 34 out of 57 goods have statistically significant quality slopes in all 19 years of our sample.\footnote{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 Table 2 of the Online Appendix at http://mypage.iu.edu/~vlugovsk/online_appendix.pdf} 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, 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, Jewelry, Outdoor furniture, and Winter/water sport equipment, and the smallest for Clothes washers, Clothes dryers, Microwave ovens, Lawn and garden equipment, and Vacuum. These estimates are consistent with Bils and Klenow’s (2001) 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.\(^38\)

The estimated slopes exhibit varying degrees of intertemporal variation: the coefficient of variation is between 0.05 and 0.91 for 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 3 shows that Color televisions and Radios experience an overall increasing trend, while Glassware and Jewelry experience an overall declining trend. Other goods, such as Computers and Cars, exhibit a weak overall trend. Thus, we are not likely to explain the variation with some common factor, such as gradual technological progress, for all goods.

\(^{38}\)Goldberg (1996) did not find evidence of a correlation between the markups of cars and a household’s income. We believe that it is less likely to be the case for the other goods in our sample since the ability of sellers to discriminate based on consumer’s income is potentially higher for vehicles than for other goods in our samples given that the price is negotiated for every transaction.
3.3 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 predict the QS to increase in the cost elasticity of quality (see Lemma 2). We test these predictions by regressing the QS on the cost elasticity of quality 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 returns-to-quality parameter at the 4-digit SITC level, which is an inverse of the cost elasticity of quality in our paper. For each SITC good, the estimate is constant across countries and time periods, and it can be interpreted as the average cost elasticity of quality across goods.

---

(a) Increasing Trend  
(b) Decreasing Trend  
(c) Weak Trend

Figure 3: Examples of Different Trend Patterns across Estimated Quality Slopes.
quality across exporters and years. To control for the good-specific preference parameters, we use the product-specific elasticity of substitution also estimated by Feenstra and Romalis (2014) at the 4-digit SITC level.\footnote{See Feenstra and Romalis (2014) for the details on the estimation procedure. Broda and Weinstein (2006) and Soderbery (2014) also estimate the elasticity of the substitution for the United States, but, for consistency, we draw from the estimates in Feenstra and Romalis (2014) obtained from worldwide trade data.}

First, we match the 57 durable goods from the CE data with the closest 4-digit SITC code 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 SITC codes that map into one CE good, we average the Feenstra and Romalis (2014) elasticity estimates across all 4-digit SITC codes and match the mean to the CE good. For the goods with multiple CE goods that correspond to one 4-digit SITC code, we assign the 4-digit SITC code to each CE good. There are a few goods for which we find no corresponding 4-digit SITC code. After dropping the latter goods from our sample, there are 45 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 cost elasticity of quality ($\hat{\gamma}_g$) and elasticity of substitution ($\hat{\varepsilon}_g$) with year-fixed effects to control for time-specific factors affecting all quality slope estimates:\footnote{Observations are clustered by CE good.}

$$\log \hat{\theta}_{gt} = -0.25 - 1.30 \times \log \hat{\gamma}_g + 0.25 \times \log \hat{\varepsilon}_g + D_t + \epsilon_{gt}. \quad (16)$$

The corresponding $R^2$ is 0.20 and the number of observations is 1,190.

In the cross-sectional specification, we modify our dependent variable by averaging our yearly quality slope estimates for each good ($\tilde{\theta}_g$):

$$\log \tilde{\theta}_g = -0.35 - 1.20 \times \log \hat{\gamma}_g + 0.24 \times \log \hat{\varepsilon}_g + \epsilon_g. \quad (17)$$
The corresponding $R^2$ is 0.32 and the number of observations is 45.

The results from both specifications confirm our theoretical prediction: the quality slope decreases in the cost elasticity of quality. To provide a quantitative interpretation of our results, we also estimate the standardized (beta) coefficients of the cost elasticity of quality and elasticity of substitution, which are 0.40 and $-0.40$, respectively. These estimates allow us to attribute 50% of the explained variation in quality slopes to preferences and 50% to technology. That is technology is likely to be as important as preferences in shaping out households’ non-homothetic consumption patterns.

4 Tariffs, Quality Slopes, and Price Dispersion

In this section, we test whether, as predicted by our model, the estimated quality slopes and corresponding rich-to-poor price dispersion increase in the tariffs on southern-produced goods and decrease in the tariffs on northern-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.

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 between 1989 and 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.

A more detailed description follows below. The full list of countries in each group is presented in Table 3 of the Online Appendix at [http://mypage.iu.edu/~vlugovsk/online appendix.pdf](http://mypage.iu.edu/~vlugovsk/online appendix.pdf). We exclude low-income countries from our analysis, since we want to ensure a minimum level of technological development for a given country sufficient for quality differentiation.

27
In particular, we match the 57 goods from the CE data with the closest 10-digit level HS categories according to their descriptions. For most goods, we find the one-to-one mapping.

We let 30 high-income OECD members represent North and refer to them 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 simple and 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. To address this concern, we calculate the weighted average tariff rates for each exporter for 1989 and 2007.\(^4^3\) 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.

![Figure 4: Trends in the U.S. Tariffs across Exporter Groups](http://mypage.iu.edu/~vlugovsk/online_appendix.pdf)

Between 1989 and 2007, for almost all products in our sample, there is a significant decrease in both simple average and 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 4, we observe pronounced differences in variation of the high- and middle-income tariffs.

\(^4^3\)The calculated weighted tariffs for each product are available in Table 4 of the Online Appendix at http://mypage.iu.edu/~vlugovsk/online_appendix.pdf
tariffs over time. This is important because the empirical test of our predictions relies on having sufficient variation in tariffs on imports from both HICs and MICs.

![U.S. Import Share from Middle-Income Countries](image)

**Figure 5: U.S. Product-Level Import Shares from Middle-Income Countries in 2007 and 1989.**

While we do not directly employ import shares in our regression analysis, theoretically 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 5, 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.

To account for the effects of technological diffusion, we draw data on the country-specific imports of manufactures 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

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44 The product-level statistics on the intertemporal variation in tariffs are available in the Online Appendix at [http://mypage.iu.edu/~vlugovsk/online_appendix.pdf](http://mypage.iu.edu/~vlugovsk/online_appendix.pdf).

45 As a robustness check, we estimate an alternative specification that includes import shares and confirm that the estimates have similar economic significance as the main specification.

29
Table 2: Summary Statistics of Proxies for Technological Diffusion, FDI and Imports of Manufactures to Middle-Income Countries (as percent of GDP).

<table>
<thead>
<tr>
<th>X (percent of GDP)</th>
<th>Mean</th>
<th>Median</th>
<th>St. Dev</th>
<th>Corr(X,τ_H)</th>
<th>Corr(X,τ_M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI</td>
<td>3.02</td>
<td>3.13</td>
<td>1.13</td>
<td>-0.1</td>
<td>-0.1</td>
</tr>
<tr>
<td>Imports of Manufactures</td>
<td>19.60</td>
<td>18.95</td>
<td>6.84</td>
<td>-0.21</td>
<td>-0.17</td>
</tr>
</tbody>
</table>

1_τ_H is the log of simple average U.S. tariff on goods from High-income countries;
2_τ_M is the log of simple average U.S. tariff on goods from Middle-income countries.

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 simple average tariffs are rather low.

4.2 Estimation and Results

Baseline Model

Following Proposition 2 we estimate the effects of tariffs on high- and middle-income exporters on the estimated quality slope \( \hat{\theta}_{gt} \) using the following specification:

\[
\hat{\theta}_{gt} = \text{Const} + D_g + D_t + \beta_1 \log \tau_{gt}^H + \beta_2 \log \tau_{gt}^M + \epsilon_{gt},
\]

(18)

where subscripts \( g \) and \( t \) denote good \( g \) and time period \( t \), respectively, and \( \tau_{gt}^H \) and \( \tau_{gt}^M \) are the simple 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 (18) with weighted least squares, where the weights are the inverse of the estimated standard errors.

Column (1) of Table 3 provides our baseline set of estimates, which are based on speci-
Table 3: The Effect of Tariffs on the U.S. Quality Slopes (with Simple Mean Tariffs)

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Log of tariff on HICs</td>
<td>-2.40***</td>
<td>-2.19***</td>
<td>-1.52**</td>
<td>-2.45***</td>
<td>-2.08***</td>
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<td>(0.65)</td>
<td>(0.64)</td>
<td>(0.63)</td>
<td>(0.62)</td>
</tr>
<tr>
<td>Log of tariff on MICs</td>
<td>0.68***</td>
<td>0.64**</td>
<td>2.74***</td>
<td>0.68***</td>
<td>1.29***</td>
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<tr>
<td></td>
<td>(0.26)</td>
<td>(0.26)</td>
<td>(0.79)</td>
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<td>(0.35)</td>
</tr>
<tr>
<td>X</td>
<td>-0.00*</td>
<td>-0.00</td>
<td>0.01</td>
<td>0.02**</td>
<td></td>
</tr>
<tr>
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<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.01)</td>
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</tr>
<tr>
<td>Log of tariff on MICs * X</td>
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<td>-0.42**</td>
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<td>(0.05)</td>
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</tr>
<tr>
<td>Constant</td>
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<td>0.76***</td>
<td>0.69***</td>
<td>0.73***</td>
<td>0.69***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
</tbody>
</table>

Adj. R-squared 0.66 0.66 0.66 0.66 0.66
No. Obs. 1,074 1,074 1,074 1,074 1,074

Notes:
1. Exporters are classified in HICs and MICs using the World Bank classification.
2. Regressions are weighted by the inverse of the standard errors of QEC estimates.
3. Year and product fixed effects in all regressions.
4. Robust standard errors, significance * .10 ** .05 *** .01.
5. Tariff data is not available for some goods in some years (9 missing observations).

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 ($\hat{\beta}_1 < 0, \hat{\beta}_2 > 0$).

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. The median quality slope decreases by 3.3% for a 1% increase in the tariff on goods from HICs and increases by 1% for a 1% increase in the tariff on goods from MICs.

**Technological Diffusion**

As stated in Proposition 4, 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 with an interaction term between the simple average tariff on imports from the MICs and a proxy of technological diffusion $X_{gt}$ (we discuss the proxies...
\[
\hat{\theta}_{gt} = \text{Const} + D_g + D_t + \beta_1 \log \tau_{gt}^H + \beta_2 \log \tau_{gt}^M + \beta_3 X_{gt} + \beta_4 \log \tau_{gt}^M X_{gt} + \epsilon_{gt}.
\] (19)

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. 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.

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 manufactures to zero for column (3) and the FDI inflows to zero for column (5). 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 3.7%. This is almost four times as high as the baseline 1%, which indirectly shows a strong effect of manufacturers’ imports on the technological diffusion. The corresponding effect in the absence of FDI is somewhat lower, 1.8%, but it is still higher than the baseline 1%.

\(^{46}\)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.
4.3 The Effect of Tariffs on Price Dispersion

The estimates in Section 4.2 suggest that the quality slope, consistent with our theory, increases in the tariff on goods from HICs and decreases in the tariff on goods from MICs. Our theory also predicts that the price dispersion will change when quality slopes change. In this section, we will quantify the effect of tariffs on price dispersion through quality slopes. Changes in tariffs increase the price dispersion, on average, by 9% and explain 31% of the average increase in price dispersion observed in the data.

We begin by defining raw price dispersion ($PD$) as the ratio of the 90th percentile and the 10th percentile of the raw prices of each good in a given year in the CE data. Next, we calculate the rich-to-poor price dispersion ($\hat{PD}$) using the quality slopes estimates from the first stage as follows:

$$\hat{PD}_{gt} = \left( \frac{\hat{p}_{High}}{\hat{p}_{Low}} \right)_{gt} = \left( \frac{c^{High}}{c^{Low}} \right)_{gt} \hat{\theta}_{gt}$$

(20)

where $c$ is households’ non-durable expenditures and $\hat{\theta}_{gt}$ is the quality slope estimate from the first-stage specification (15). In our main specification, $High$ and $Low$ are the 90th percentile and 10th percentile of predicted prices or households’ non-durable expenditures, respectively. Note that, in contrast to $PD$, $\hat{PD}$ is carefully constructed to reflect the ratio of prices paid by rich and poor households.

Having calculated the raw price dispersion and the rich-to-poor price dispersion, we then estimate the following specification:

$$\log \hat{PD}_{gt} = \text{Const} + D_g + D_t + \beta_1 \log \tau_{gt}^H + \beta_2 \log \tau_{gt}^M + \epsilon_{gt},$$

(21)

where subscripts $g$ and $t$ denote good $g$ and time period $t$, respectively, and $\tau_{gt}^H$ and $\tau_{gt}^M$ are the simple 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
Table 4: The Effect of Tariffs on Price Dispersion

<table>
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<tr>
<th>Left-hand side variable:</th>
<th>log $PD$</th>
<th>log $\hat{PD}$</th>
<th>log $PD - \hat{PD}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of tariff on High-Income Countries</td>
<td>-3.71***</td>
<td>-2.90***</td>
<td>-0.81</td>
</tr>
<tr>
<td></td>
<td>(0.75)</td>
<td>(0.80)</td>
<td>(0.76)</td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries</td>
<td>0.67*</td>
<td>0.64*</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>(0.35)</td>
<td>(0.37)</td>
<td>(0.35)</td>
</tr>
<tr>
<td>Constant</td>
<td>2.66***</td>
<td>0.92***</td>
<td>1.74***</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.06)</td>
<td>(0.07)</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.86</td>
<td>0.67</td>
<td>0.69</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>1,074</td>
<td>1,074</td>
<td>1,074</td>
</tr>
</tbody>
</table>

Notes:
1. $PD$ is the raw price dispersion defined as the ratio of the 90th percentile to 10th percentile of raw prices paid by households for a given good and year and $PD$ is the price dispersion defined as in equation (23).
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) presents the results. The estimates are statistically significant and in line with our theoretical predictions: price dispersion decreases in the tariff on goods originating from the HICs and increases in the tariffs on goods from the MICs. Column (3) of Table (4) suggests that 1% increase in tariffs on goods from HICs decreases price dispersion, $\hat{PD}$, by 2.9%, while 1% increase in tariffs on goods from MICs increases $\hat{PD}$ by 0.64%. Column (2) shows that tariffs also affect the raw price dispersion, but they do not have any effect on the difference between $PD$ and $\hat{PD}$. In other words, the effect of tariffs on the overall price dispersion is channeled mainly through their effects on the rich-to-poor price dispersion (inferred from the quality slopes).

To quantify the effect of changes in tariffs on the rich-to-poor price dispersion, we use the predicted values of price dispersion from (21) to calculate percentage changes in price dispersion from 1989 to 2007 for each good. Because of changes in tariff rates from 1989 to 2007, all goods but Trucks show an increase in price dispersion and the price dispersion for the median good increases by 17% as illustrated in Figure 6. The weighted-average increase in price dispersion across goods in our sample is 11%, where weights are the share of each good.

34
good in households’ consumption of durables.

![Rich-to-Poor Price Dispersion for the Median Good](image)

Figure 6: Rich-to-Poor Price Dispersion for the Median Good from 1989 to 2007.

### 4.4 Robustness Checks

We perform several robustness exercises to check the sensitivity of the second-stage results. 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 presented in Tables 5 show that the sign, magnitudes, and significance patterns are consistent with our baseline proxies of technology diffusion.

Second, we remove China and Mexico from our sample. During the time period in our sample, two major episodes of trade liberalization occur between the U.S. and China and Mexico, its main trade partners. To check whether our results are mainly driven by trade liberalization with China and Mexico, we exclude China and Mexico from our sample of exporters and re-estimate specifications (18) and (19). We report the results in Table 6. Since trade with Mexico and China represents a significant part of U.S.’s trade, it is not surprising that the magnitudes of the coefficients are smaller. Importantly, the signs are consistent with our original results reported in Table 3.
Third, we experiment with alternative measures of tariffs. In particular, in specifications (18) and (19), we use trade-weighted average tariffs instead of simple-average tariffs. Table 7 shows that the coefficients change slightly in magnitude, but the signs and significance levels are consistent with our original results, reported in Table 3.

Since theoretically we rely on changes in northern and southern import shares to generate variation in quality slopes over time, we estimate an alternative specification that employs directly import shares (instead of tariffs):

\[
\hat{\theta}_{gt} = \text{Const} + D_g + D_t + \beta \log \text{ImpShare}_M^{gt} + \epsilon_{gt},
\]  

(22)

where subscripts \(g\) and \(t\) denote good \(g\) and time period \(t\), respectively, and \(\text{ImpShare}_M^{gt}\) is the import share from MICs, 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 first estimate (22) using OLS and the results are reported in the second column of Table 8. One concern of using import shares may be that, according to our theory, an exogenous shock to southern technology to produce a quality differentiated good can, ceteris paribus, increase the southern quality slope and, thus, increasing the average quality slope and the import share from MICs. To address this potential concern of endogeneity, we also estimate (22) using 2SLS, where we instrument the import share from MICs using simple average tariffs on goods originating from MICs and HICs. The IV estimates are reported in column (2) of Table 8. Both the OLS and IV estimate are statistically significant and have signs consistent with our theory. The IV estimate is about three times higher than the OLS estimate, suggesting that endogeneity of the import share introduces an attenuation bias in OLS estimate. Based on the IV estimate, the median quality slope decreases by 14% if the
share of imports from MICs doubles\textsuperscript{47}.

Last, we estimate the effect of the simple average tariff on price dispersion as in specification (21) using various measures of $\hat{PD}$ defined as in (23) using 80th/20th ratio, 95th/10th ratio, and 95th/5th ratio. The results are provided in Table 9. The signs and significance of the estimates are consistent with the theoretical predictions and our baseline estimates. The magnitudes of the coefficients vary slightly suggesting that tariffs on goods originating from HICs (MICs) have a stronger effect on price dispersion as we expand the price range at the top (bottom) of the price distribution.

5 Conclusion

This paper studies the effect of tariff changes on the U.S. rich-to-poor price dispersion of durable goods over time. Our model with non-homothetic preferences and trade in vertically differentiated products predicts that tariff cuts on imports from developed countries decrease the prices of higher quality goods, which induces richer households to upgrade the quality of their products. As a result, the rich-to-poor price dispersion increases. Tariff cuts on imports from developing countries, on the contrary, induce poorer households to upgrade their product quality choices and thus decrease price dispersion. Importantly, we view the households’ expenditure pattern as an equilibrium outcome, determined not only by households’ preferences for quality, but also by the exporter-specific supply-side parameter—the cost elasticity of quality.

Empirically, we combine U.S microdata on household consumption with highly disaggregated trade data and confirm these predictions. We find that, between 1989 and 2007, changes in relative tariffs on goods originating from middle-income to high-income countries have increased U.S. rich-to-poor price dispersion for the median good by 17\% . Across all

\textsuperscript{47} The economic effect of this estimate on the changes in price dispersion is very similar to the effect of the estimate in specification (21): the median increase in price dispersion from 1989 to 2007 is 17\%.
durables in our sample, the weighted-average change in rich-to-poor price dispersion is 11%, where weights are the share of each good in households’ consumption of durables.

While our goal in this paper is to show the effect of changes in tariffs on U.S. rich-to-poor price dispersion, our estimates suggest that one should consider quality-adjusted prices when analyzing trends in real income since the product quality bought by different income groups does not stay constant or change in the same way over time. We leave this for future research.
References


6 Appendix

6.1 Appendix A: Proofs

*Proof of Proposition 1*

From equation (6), for any two households $h'$ and $h''$ with the expenditures on the numeraire $c' > c''$, a higher quality slope of good $g$, $\theta_g$, automatically corresponds to a higher ratio of prices, $p_{h'g}/p_{h''g}$, and thus to a higher price dispersion. ■

*Proof of Lemma 3*

A higher tariff on northern good $\tau'_{gN} > \tau_{gN}$ will decrease the equilibrium consumption of quality of good $g$ for households choosing northern varieties of $g$ (follows directly from the equilibrium condition (10)), but will not affect the utility from consuming the southern-produced quality. Therefore, a household with an intermediate income level $I_{d_g}$ will strictly prefer southern quality $z_g^-$ to the new equilibrium northern quality (which will be lower than $z_g^+$). As a result, the new intermediate income level, at which a household is indifferent between buying southern and northern quality, $I'_{d_g}$, will be higher than the original $I_{d_g}$.
Thus, the share of consumers buying the southern quality will increase: $F(I_{dg}^\tau_{gN}) > F(I_{dg}(\tau_{gN}))$.

Similarly, a higher tariff on southern goods, $\tau_{gS}^\prime > \tau_{gS}$, will decrease the southern-produced equilibrium quality for a household with intermediate income $I_{dg}$, while leaving northern-produced equilibrium quality for the same household unchanged. Thus, the new intermediate income level, at which a household is indifferent between buying southern and northern quality, $I_{dg}''$, will be lower than the original $I_{dg}$. Thus, the share of consumers buying the southern quality will decrease: $F(I_{dg}''(\tau_{gN})) < F(I_{dg}(\tau_{gN}))$.

**Proof of Proposition 2**

![Figure 7: The Effect of a Higher Southern Tariff.](image)

As indicated by Lemma 3, a higher tariff on southern-produced varieties of good $g$ decreases the share of consumers buying southern-produced varieties and increases the share of consumers buying northern-produced varieties. These shifts are illustrated by the two arrows in Figure 7. As a result, a higher tariff on southern-produced varieties of good $g$ will decrease the average quality slope of $g$, which is a weighted average of the ‘southern’ and ‘northern’ quality slopes (see eq. (13)), since the southern quality slope is flatter than then northern quality slope.

A higher tariff on the northern-produced varieties of good $g$, on the other hand, will increase the share of consumers buying southern-produced varieties of $g$ (see Lemma 3), and thus will cause a decrease in the weighted-average quality slope (see eq. (13)).

**Proof of Proposition 3**

The equilibrium value of the price dispersion of good $g$ (see Definition 1) can be derived using...
equations (10) and (11) as

\[
\frac{p_g(\bar{c})}{p_g(\underline{c})} = \frac{\alpha_gN \left( \frac{\sigma^{1/\gamma} \frac{1}{\epsilon_g-1} \gamma_gN/(1/\epsilon_g+\gamma_gN-1)}{\alpha_gN\gamma_gN T_gN} \right)}{\alpha_gS \left( \frac{\sigma^{1/\gamma} \frac{1}{\epsilon_g-1} \gamma_gS/(1/\epsilon_g+\gamma_gS-1)}{\alpha_gS\gamma_gS T_gS} \right)}.
\]

(23)

From equation (23), the qualitative effects of import tariffs on the price dispersion are:

\[
\frac{\partial p_g(\bar{c})}{\partial \tau gN} = \frac{1}{\epsilon_g-1} \frac{p_g(\bar{c})}{p_g(\underline{c}) \tau gN} < 0 \quad \text{and} \quad \frac{\partial p_g(\bar{c})}{\partial \tau gS} = -\frac{1}{\epsilon_g-1} \frac{p_g(\bar{c})}{p_g(\underline{c}) \tau gS} > 0,
\]

since \(1/\epsilon_g < 1\), and \(\gamma_gS, \gamma_gN > 1\).

Proof of Proposition 4

Note that technological diffusion decreases the share of Home’s households consuming varieties produced with the original southern technology. Thus the average quality slope is always steeper in the presence of technological diffusion (as also indicated by equation (14)). Thus, even if the absolute number of consumers switching from one quality slope to another is the same as in the model with no diffusion, the relative change will be smaller, since the starting slope has a greater magnitude.

In addition, there are several cases when even the absolute change will be smaller. For example, if the diffused technology completely replaced the original southern technology, a higher tariff on the southern-produced varieties (which in the model with no diffusion has a positive effect on the average quality slope) will have no effect on the average QS, since it is already at its maximum. Households buying the quality produced under the original southern technology, the absolute effect of the tariff on the average quality slope will be even smaller under technology diffusion than under no technology diffusion.

6.2 Appendix B: Additional Tables
Table 5: The Effect of Tariffs on the U.S. Quality Slopes (Lagged Imports and FDI in the MICs)

<table>
<thead>
<tr>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
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<tbody>
<tr>
<td>X is One-Lag Imports of Manufactures (perc. of GDP) into Middle-Income Countries in specification (2) and (3)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X is One-Lag of FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log of tariff on High-Income Countries</td>
<td>-2.40***</td>
<td>-2.24***</td>
<td>-1.55**</td>
<td>-2.44***</td>
<td>-2.19***</td>
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<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries * X</td>
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<td>-0.30*</td>
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<td>(0.04)</td>
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</tr>
<tr>
<td>Constant</td>
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<td>0.76***</td>
<td>0.69***</td>
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<tr>
<td>Adj. R-squared</td>
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<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
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</tr>
</tbody>
</table>

Table 6: The Effect of Tariffs on the U.S. Quality Slopes (Excluding China and Mexico)

Sample of exporters excludes China and Mexico

<table>
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<tr>
<th></th>
<th>(1)</th>
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<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X is Imports of Manufactures (percent of GDP) into Middle-Income Countries in specification (2) and (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X is FDI Inflows (percent of GDP) into Middle-Income Countries in specification (4) and (5)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Log of tariff on High-Income Countries</td>
<td>-2.18***</td>
<td>-2.20***</td>
<td>-2.07***</td>
<td>-2.11***</td>
<td>-1.84***</td>
</tr>
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<td>(0.61)</td>
<td>(0.64)</td>
<td>(0.61)</td>
<td>(0.64)</td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries</td>
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<td>0.49*</td>
<td>0.79*</td>
<td>0.47*</td>
<td>0.91**</td>
</tr>
<tr>
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<td>(0.25)</td>
<td>(0.44)</td>
<td>(0.25)</td>
<td>(0.37)</td>
</tr>
<tr>
<td>X</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries * X</td>
<td>-0.02</td>
<td></td>
<td>-0.24***</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.16)</td>
<td>(0.16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.74***</td>
<td>0.73***</td>
<td>0.71***</td>
<td>0.74***</td>
<td>0.73***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>1,061</td>
<td>1,061</td>
<td>1,061</td>
<td>1,061</td>
<td>1,061</td>
</tr>
</tbody>
</table>

Notes:
1. Tariff rates are simple average of ad-valorem tariff rates.
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>
<thead>
<tr>
<th></th>
<th>(1) Baseline</th>
<th>(2) X=Imp. of Manuf.</th>
<th>(3) X=FDI</th>
<th>(4) X=FDI</th>
<th>(5) X=FDI</th>
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</thead>
<tbody>
<tr>
<td>Log of tariff on High-Income Countries</td>
<td>-2.49***</td>
<td>-2.14**</td>
<td>-1.90**</td>
<td>-2.53***</td>
<td>-2.33***</td>
</tr>
<tr>
<td></td>
<td>(0.81)</td>
<td>(0.87)</td>
<td>(0.88)</td>
<td>(0.81)</td>
<td>(0.83)</td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries</td>
<td>1.40***</td>
<td>1.33**</td>
<td>2.87***</td>
<td>1.39**</td>
<td>1.66***</td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.54)</td>
<td>(0.66)</td>
<td>(0.54)</td>
<td>(0.52)</td>
</tr>
<tr>
<td>X</td>
<td>-0.00</td>
<td>-0.00</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries * X</td>
<td>-0.10***</td>
<td>-0.19</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>(0.04)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.73***</td>
<td>0.73***</td>
<td>0.69***</td>
<td>0.72***</td>
<td>0.70***</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.09)</td>
<td>(0.06)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>No. Obs.</td>
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<td>1074</td>
<td>1074</td>
<td>1074</td>
<td>1074</td>
</tr>
</tbody>
</table>

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 Import Share from MICs on the U.S. Quality Slopes, 1989-2007.

<table>
<thead>
<tr>
<th></th>
<th>OLS</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of Import Share from Middle-Income Countries</td>
<td>-0.04***</td>
<td>-0.15***</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.62***</td>
<td>0.50***</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>First Stage F-stat</td>
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<td>88.20</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.66</td>
<td>0.64</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>1,074</td>
<td>1,074</td>
</tr>
</tbody>
</table>

Notes:
1. Exporters are classified in HICs and MICs using the World Bank classification.
2. Regressions are weighted by the inverse of the standard errors of QEC estimates.
3. Year and product fixed effects in all regressions.
4. Robust standard errors, significance * .10 ** .05 *** .01.
Table 9: The Effect of Tariffs on Various Measures of $\hat{PD}$

Tariff is defined as simple-mean ad-valorem tariff

<table>
<thead>
<tr>
<th>$PD$ defined as</th>
<th>80th/20th</th>
<th>95th/10th</th>
<th>95th/5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of tariff on High-Income Countries</td>
<td>-2.00***</td>
<td>-3.39***</td>
<td>-3.76***</td>
</tr>
<tr>
<td></td>
<td>(0.54)</td>
<td>(0.93)</td>
<td>(1.06)</td>
</tr>
<tr>
<td>Log of tariff on Middle-Income Countries</td>
<td>0.50**</td>
<td>0.83**</td>
<td>0.90*</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.41)</td>
<td>(0.47)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.60***</td>
<td>1.04***</td>
<td>1.18***</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.07)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Adj. R-squared</td>
<td>0.67</td>
<td>0.68</td>
<td>0.68</td>
</tr>
<tr>
<td>No. Obs.</td>
<td>1,074</td>
<td>1,074</td>
<td>1,074</td>
</tr>
</tbody>
</table>

Notes:
1. $PD$ is the price dispersion defined as in equation (23).
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.