Competing on Price and Quality: Theory and Evidence from Trade Data*

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February 11, 2019

Abstract

Import competition induces firms either to reduce their markup, upgrade their quality, or both. Modern models of international trade typically consider one margin of adjustment to explain the consequences of import competition. However, examining U.S. import data suggests that firms actively respond by adjusting both quality and markup. This paper develops and calibrates a Ricardian model of trade which incorporates the endogenous response of quality and markup to import competition. Countries are heterogeneous both in physical efficiency and quality capability. Firms engage in a two-dimensional Bertrand competition in which they simultaneously choose the price and quality of output. Estimation results indicate that developed countries are more productive both in physical and quality production. Moreover, in response to import competition, developed countries mainly upgrade quality, while developing countries mainly reduce the markup. Ignoring the quality channel would underestimate the gains from trade that the U.S. derives with developed countries and overestimate the gains from trade with developing countries. The counterfactual experiment indicates as the U.S. economy grows, it benefits more from free trade with quality-capable countries than with countries which are less capable.

JEL: F12, F13, F14, F61, O31, O57.

Keywords: Import Competition, Quality Upgrading, Markup Reduction.

*An earlier version of this paper was circulated under the title "Import Competition and the Endogenous Response of Quality and Markup: Evidence from U.S. Import Data". I am grateful to my adviser Jonathan Eaton for his substantial guidance and support and to James Tybout and Stephen Yeaple for fruitful discussions.

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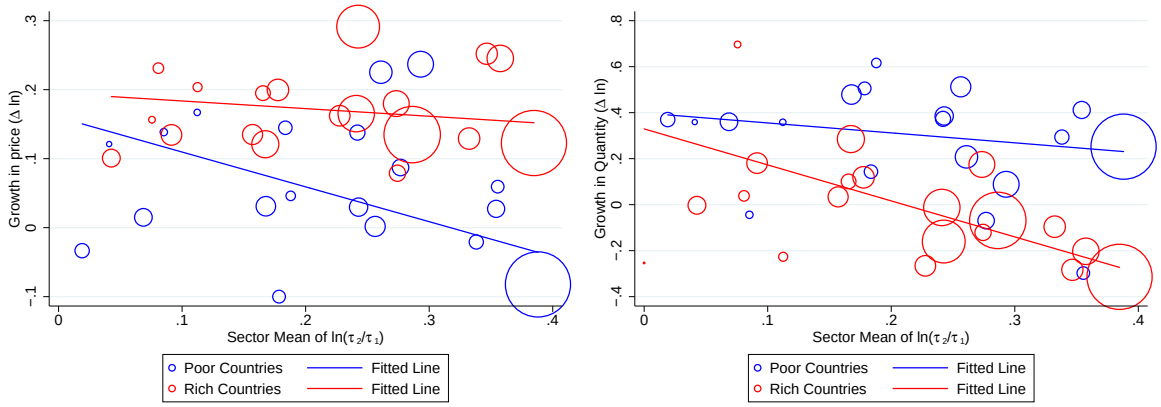
1 Introduction

How do firms respond to import competition? This is a key question that interests not only the academic community, but also policy makers, since it has direct consequences on the welfare of consumers. In response to an intensified competition, a firm can either reduce its markup to maintain market share, upgrade the quality to differentiate itself from its competitors, or both. However, investigating U.S. import data suggests that firms actively adjust both margins in response to an increase in competition resulting from China's accession to the WTO.

This two-dimensional response to import competition is a key factor in understanding the welfare implications of policies influencing import competition. However, modern models of international trade are not able to generate this empirically-documented pattern because they typically focus only on one mechanism: they allow firms to respond to trade shocks by changing either their markup or quality, but not both. This paper contributes to the literature by developing and calibrating a Ricardian model of trade with an endogenous choice of quality which can rationalize this empirical pattern. Based on the model, considering both margins of quality and markup is important when a country assesses the gains from trade with its trading partners.

Using U.S. import data at the most disaggregated level, I document how other exporting countries respond to China's penetration in the U.S. market after China joined WTO in 2001. Following the difference-in-difference identification strategy proposed by Pierce and Schott (2016), I use variation in the gap between Most Favorite Nation (MFN, hereafter) and non-MFN tariff rates across product categories to identify the effect of China's import competition on other exporting countries in the U.S. market: The larger the initial gap, the more uncertainty was eliminated for Chinese producers, leading to more entry by China and in turn increasing competition (Handley and Limão (2017)). Figure 1 provides a suggestive evidence about how developed and developing countries respond differentially to China's competition. Panel 1a graphs the average growth in export price of products exported by different countries to the U.S. market from 2000 to 2005 against the log difference between MFN and non-MFN tariff rates in each sector. A general pattern is that developed countries were affected less in terms of price. This pattern is also verified by a difference-in-difference specification (presented in more details in Section 2)



(a) Price Response

(b) Quantity Response

Figure 1: Differential Response of Countries

Note: Horizontal axis shows the log difference between MFN and non-MFN tariff rates in 1999 averaged across HS-8 product categories within each sector. Horizontal axis indicates average growth in price and quantity from 2000 to 2005. Countries are categorized to developed and developing according to the median level of GDP per capita. Each circle corresponds to a sector and its size is proportional to the number of observations in that sector.

which controls for various fixed effects. Regression results show that increasing the tariff gap from the 25th percentile of its distribution (22.9%) to the 75th percentile (46.4%) would lead other exporting countries to decrease their price on average by 0.024 log points. I also let the price response depend on the GDP per capita of the exporting country, finding that developed countries cut prices less than developing countries.

These results can be explained by extant theories in two different ways: (i) China's import penetration makes competition in the U.S. market tougher for other exporting countries and consequently leads firms to innovate more in order to escape the imported competition. Developed countries are more efficient in innovation, so they can more easily escape Chinese competition and will be less affected in terms of price; and (ii) In the spirit of Holmes and Stevens (2014), Chinese competition is targeting mostly products originating from less developed countries because they produce similar standardized goods. Hence, the market for products imported from developed countries would be hurt less by a Chinese import shock, making these products less responsive in terms of price. However, looking at the average growth of quantities exported to the U.S. in Figure 1b reveals a surprising fact: Chinese

import competition caused developed countries to reduce their shipments to the U.S. market more than developing countries, a pattern which is also confirmed by a difference-in-difference regression in Section 2. This is completely in contrast with extant theories which emphasize that developed countries either are hurt less by Chinese import competition or can escape it more easily.

I argue that upon considering the effect of import competition on the *quality-adjusted* price rather than the nominal price, this heterogeneity in response can be rationalized. The main focus of this paper is to develop a model of international trade which can generate this heterogeneous pattern in response of countries and examine its implications for welfare calculation. The model is an extension to the Bernard et al. (2003) (BEJK, henceforth) where firms are competing on both margins of price and quality simultaneously. The model can tractably features a two-dimensional Bertrand competition to nest firms' response on both margins of price and quality. In the model, countries are different in two aspects: their physical efficiency reflecting the amount of output a country can make using a bundle of inputs, and quality capability reflecting the ability of a country in producing high-quality products. Firms need to choose both the price and quality of their outputs when they sell in the market. They engage in a head-to-head competition with each other in the sense that the firm which can provide the lowest quality-adjusted price will be the only seller of product in the market.

If a country lowers trade barriers with one of its trading partners, then incumbent firms, in order to remain active sellers, adjust both margins of price and quality: firms from developed countries with greater capacity to produce quality products mainly find it more efficient to upgrade their output quality, while firms from developing countries react mainly on price margin by cutting down the markup.

Using data on bilateral trade flows and average export price of countries in 2000, I estimate the model and back out country level physical efficiency and quality capability simultaneously. Results show that developed countries are not only more efficient in physical production, but are also more capable in quality production. Moreover, I simulate the U.S. economy using the estimated model and show how an increase in China's penetration in the U.S. market generates documented empirical evidence about the differential response of countries to increased competition from China.

Finally, I implement two types of counterfactual experiments. The first shows

that the quality channel is quantitatively important in terms of welfare implications, indicating that when a country assesses the benefit of liberalizing trade with each of its partners, ignoring the quality channel leads to mis-measurement of welfare gains. Specifically, the U.S. gains from trade with developed countries are underestimated, while its gains from trade with developing countries are overestimated. The second counterfactual reveals that if the U.S. economy continues to grow, it would benefit from free trade with quality-capable countries such as Japan more than countries providing cheap goods but at low quality.

Related Literature. This paper is related to extensive literature concerning the effects of import competition on firm performance. There are two broad but distinct strands in the literature that try to answer this question. The first strand considers the response on the price margin and argues that import competition leads to firms losing their market share and in turn reducing their markups– an implication which is called "pro-competitive" effect of trade. This fact has not only been theoretically rationalized with different market structures (see Melitz and Ottaviano (2008) for monopolistic competition and De Blas and Russ (2015) for Bertrand competition), but also verified empirically by many firm-level studies; see e.g. Levinsohn (1993), Krishna and Mitra (1998), Edmond et al. (2015), Brandt et al. (2017), Feenstra and Weinstein (2017), Hsu et al. (2017). The second strand investigates the impact of import competition on innovation activity of firms, which in some papers is interpreted as improving quality of output. Theoretical models on this margin of response stem from the pioneering works of Boone (2000) and Aghion et al. (2005). Aghion et al. (2005) predicts differential responses to competition based on a firm's position in the technology ladder. Frontier firms have more incentive to innovate because they could escape the competition by innovating more ("escape-competition effect"). On the other hand, laggard firms would be discouraged from innovating since competition reduces their post-innovation rent ("Schumpeterian effect"). There are several papers which examine the effect of trade shock either on general innovation activity or technological progress of firms (see e.g. Bertschek (1995), Bustos (2011), Hombert and Matray (2015), Bloom et al. (2016), Autor et al. (2017), Aghion et al. (2018)), or more specifically, on the quality-upgrading behavior of firms (see e.g. Verhoogen (2008), Amiti and Khandelwal (2013), Fernandes and Paunov (2013), Smeets et al. (2016), Medina (2017)). I contribute to this literature

by developing a unifying model which nests both margins of adjustment in a two-dimensional Bertrand competition. While having the richness in different types of firm behavior, the model maintains tractability, thus implying its potential application in international trade studies.

Within the narrower part of this literature that focuses on the effect of globalization on quality upgrading, there are three groups of studies which consider different channels through which globalization triggers quality upgrading. The first group, which includes Fan et al. (2015), Bas and Strauss-Kahn (2015) and Eslava et al. (2018), argues that globalization reduces the price of high-quality inputs and thus makes it more profitable for firms to produce high-quality products. The second group (Bustos (2011), Antoniades (2015) and Eslava et al. (2018)) focuses on the role of economies of scale for quality: international trade enlarges the market in which firms can sell their products, and hence the expanded revenue justifies fixed costs of quality improvement. The third group (Medina (2017) and Bloom et al. (2018)) relies on factor reallocation within firms: import competition decreases the return to fixed factors that cannot be adjusted instantaneously. Therefore, firms re-assign these factors to produce products differentiated from imported products in order to escape competition. This paper, however, proposes a new channel for quality improvement: it is neither due to cheaper intermediates nor the interaction of fixed costs and market size; rather, it is due to the direct effect of competition in the output market. In fact, firms engage in a head-to-head competition with foreign firms. This type of competition is a new channel which forces the incumbents to increase quality in order to survive. In this sense, firms are not escaping competition (as they do in the third group), but rather are confronting it, which enables them to provide high-quality products in the same market in which import competition is intensified rather than direct their sales toward other markets.

This paper is also related to the literature on cross-country differences in endogenous quality choice. In many papers, the well-known fact that developed countries charge higher prices for their exports is attributed to the quality of their products. The reason developed countries endogenously produce at a higher level of quality is either due to their proximity to the markets appreciating high-quality goods (e.g. Hallak (2006)), which is in known as "Linder Hypothesis", or the fact that they are more productive and hence are able to produce high-quality goods (e.g. Feenstra and Romalis (2014)). My paper departs from the standard tradition in the litera-

ture and differentiates between physical productivity and quality productivity. In this sense, it is similar to Hallak and Sivadasan (2013), who consider two types of productivity for firms: process productivity (i.e. the ability of a firm in transforming input to physical units of output), and product productivity (i.e. the ability of a firm to produce high-quality goods). This paper distinguishes between these two types of productivity, but at the country level. I show that distinguishing between physical and quality productivity is crucial in capturing differential responses of countries to import competition.

The remainder of this paper is organized as follows. Section 2 documents empirical regularities in data showing the heterogeneous response of countries when facing import competition in the U.S. market. Section 3 develops a model of import competition that can generate these empirical regularities. Section 4 describes the estimation procedure, and Section 5 presents the results. Section 6 performs two counterfactual experiments and Section 7 concludes.

2 Empirical Regularities

In this section, first I present three empirical facts to support the idea that firms respond to import competition along both margins of price and quality and this response is heterogeneous across countries. Then I verify the validity of this heterogeneous response by some robustness exercises.

2.1 Export Price and Quantity Responses

To assess the heterogeneous response of countries to the shock to import competition, I use China's accession to WTO as a natural experiment. Tariff act of 1930 made U.S. import from non-market economies (including China) subject to high tariff rates known as "non-MFN" or "column 2" rates. However, the U.S. president was allowed by trade act of 1974 to temporarily extend low tariff rates, known as "MFN" or "column 1" rates, on Chinese products on an annual basis and conditional on the approval of congress. Beginning on 1980 until 2002, the U.S. government kept approving low MFN tariff rates for China but the problem was that this approval had to be certified by congress every year which was politically uncertain. Consequently, the uncertainty of this process deterred Chinese firms from incurring

the sunk cost of entry into the U.S. market. In 2002 and after China joined WTO, the U.S. congress granted permanent MFN rates to China. This removed all the previous uncertainty faced by Chinese firms and lead to a huge increase of China's export to the U.S. market.

The gap between MFN and non-MFN rates can serve as an indicator for the size of pre-2002 barriers. The greater the gap, the more uncertainty has been eliminated and therefore more firms would enter the U.S. market. Following Pierce and Schott (2016), I use the cross product variation in the gap between MFN and non-MFN rates to identify the differential response of countries to import competition in the U.S.. I fix the U.S. as the destination market where all countries sell their products. Using increased import competition from China after 2002, I examine how other exporting countries reacted to this intensified competition.

I use U.S. import data produced by the U.S. Census Bureau and prepared by Schott (2008). This data set records the annual value and physical quantity of 10-digit HS product categories that are exported by all countries into the U.S.. In the following, value, quantity and price (unit value) of product h exported by country c to the U.S. at time t are denoted by v_{cht}, x_{cht} and p_{cht}, respectively. v_{cht} and x_{cht} are directly recorded in the data, but I construct the price data by dividing the value by quantity: $p_{cht} = v_{cht}/x_{cht}$. To reduce the measurement error effects of import data, I removed all the observations which report a total value of import less than \$7500 in constant 1989 dollars. The gap between two tariff schedules is defined as

$$Gap_g = Non\ MFNRate_g - MFNRate_g \tag{1}$$

where g stands for 8-digit HS product category. Ad valorem equivalents of MFN and Non-MFN tariff rates are for 1999 and provided by Feenstra et al. (2002).

To measure the effect of Chinese competition, I use difference-in-differences (DID) specification

$$\ln p_{cht} = \alpha_1 D_t^{2002} \times Gap_g + \alpha_2 \log GDP_c \times D_t^{2002} \times Gap_g + \alpha_3 HI_{cst} + D_{ch} + D_{ct} + \varepsilon_{cht} \tag{2}$$

and regress the log of unit value of products exported by all countries except China, $\ln p_{cht}$, on the interaction of gap between MFN and Non-MFN rates associated with group g (where product h lies in) and dummy variable D_t^{2002} which takes value 1 for $t \geq 2002$. I also include country-product fixed effects (D_{ch}) to control for various

Table 1: Price Regression

	$\ln p_{cht}$	$\ln p_{cht}$	$\ln p_{cht}$
$D_t^{2002} \times Gap_g$	-0.099***	-0.212***	-0.211***
	(0.009)	(0.053)	(0.053)
$\log GDP_c \times D_t^{2002} \times Gap_g$		0.012**	0.012**
		(0.006)	(0.006)
HI_{cst}			0.027
			(0.019)
R^2	0.92	0.92	0.92
Observations	1,703,158	1,700,639	1,700,639
Country × Product FE	yes	yes	yes
Country × Year FE	yes	yes	yes

Notes: Table indicates the effect of Chinese import competition on the price of products exported by other countries to the U.S. Dependent variable is the log unit value of products imported from all exporting countries except China. Independent variables are interaction of Gap and post-2002 period and triple interaction of Gap, post-2002 period and log of exporting country's GDP per capita. Other control variable is the Herfindahl index which controls for the number of exporting firms at each country, HS4-sector and time. Data span 1992 to 2005. Robust standard errors adjusted for clustering at country × HS8-product are shown in parentheses below the estimate values. All columns include country × HS10-product country × year fixed effects. ***, ** and * indicates statistical significance at 99%, 95% and 90% level, respectively.

characteristics of product h imported from country c as well as different measurement units. Moreover, country-time fixed effects (D_{ct}) control for aggregate shocks that hit country c in year t. Table 1 indicates three specifications for regression 2. Column 1 is the baseline specification which investigates how Chinese competition affects pricing decision of other exporting countries on average. Column 2 allows for discrepancy in the response of countries by interacting $D_t^{2002} \times Gap_g$ with the log GDP per capita of exporting country. I use GDP per capita as an indicator for the country's level of development. To control for the effect of firms' exit and entry (extensive margin) on the price response, I include Herfindahl indices in column 3 as a proxy for the number of exporting firms. HI_{cst} indicates the Herfindahl index of firms located in country c which export products in the 4-digit HS product category (denoted by subscript s) to the U.S. in year t. Data for the Herfindahl indices are provided by Feenstra and Weinstein (2017).

Fact 1. *Countries, on average, respond to China's import competition by reducing export*

prices.

Column 1 of Table 1 shows that other exporting countries respond to Chinese Competition by cutting down their prices. The coefficient for the difference-in-difference term is negative and highly significant showing that on average, countries who used to export in product categories with a higher MFN gap, reduced their prices more in response to China's entry to the WTO. For example, the average country exporting products that experienced a gap removal of 0.464 (equal to 75th percentile of gap distribution) reduces their prices more by 0.024 log point (=0.102 $\times$ (0.464-0.229)) than the average country exporting products associated with 0.229 gap removal (equal to 25th percentile of gap distribution).

Fact 2. *Rich countries respond to China's import competition less than poor countries in terms of price.*

Column 2 of Table 1 allows for heterogeneity in the price response of countries by adding the triple difference term $\log GDP_c \times D_t^{2002} \times Gap_g$. I use GDP per capita data for 2001. The coefficient 0.021 of the triple difference term means that if I consider the same movement of going from 25th to 75th percentile of the gap, exporting firms from Indonesia reduce their export prices to the U.S. by 0.074 units more in log term than firms located in Germany. Therefore, I can state the second evidence related to heterogeneity of countries' responses.

Notice that column 3 confirms that Facts 1 and 2 are still valid after controlling for the number of exporting firms, i.e. they are not due to the adjustments in the extensive margin of firms.

So far, the facts can be explain by extant theories in the literature in two ways. First, we can borrow from the literature explaining the effect of competition on innovation. In the spirit of Aghion et al. (2005), one might argue that facing increased import from China, incumbent firms try to innovate more to differentiate themselves in the market and hence escape competition. And since rich countries are more efficient in innovation activities, they can more easily escape the imported competition than poor countries. That is why we see they are less impacted in terms of price. Second, and using similar argument to Holmes and Stevens (2014), we can rationalize Facts 1 and 2 by assuming that Chinese firms and firms from poor countries are producing similar standardized products while products coming from rich countries are more differentiated. So we can conclude that poor countries are more

subject to China's import competition and need to cut down their prices more than rich countries. Surprisingly, these two explanations turn out to be rejected by data.

To show this, I run the same regression as 2 but use the quantity of product h exported by country c in year t, x_{cht}, instead of price p_{cht}. Results are illustrated in Table 2.

Fact 3. *Rich countries respond to China's import competition more than poor countries in terms of shipment quantity.*

Column 1 of Table 2 shows that exporting countries on average don't change the volume of their exports in response to China's competition. However, this insensitivity is due to averaging over all countries. If we allow for the heterogeneity of response across countries as column 2 does, we see that quantity is significantly impacted by China's competition. Interestingly, estimates indicate that in contrast with Fact 2, rich countries are more responsive to China's competition: moving from 25th to 75th percentile of the gap, shipment from Germany to the U.S. decreased by 0.383 units more in log term than shipments from Indonesia. This evidence remain valid when column 3 controls for the number of exporting firms by adding the Herfindahl indices H_{cst} to the regression.

Fact 3 cant not be justified by the previous explanations for Facts 1 and 2: If rich countries are either less subject to competition from China or can escape it more easily by innovation, they should also be less affected in terms of quantity. However, evidence in Table 2 reveals the opposite.

This pattern of heterogeneous respond along different dimensions of price and quantity can not be supported by the extant models of international trade. In the following section, I develop a Ricardian model of trade with the endogenous choice of quality in which firms reacts to tougher competition on both margins of price and quality. Then I confirm that the proposed model can generate the empirical findings of this section. At the end, I show that the ability of the model to produce heterogeneous responses to import competition has important welfare implications. Before laying out the model, next sections confirms the validity of documented results by doing some robustness exercises.

Table 2: Quantity Regression

	$\ln x_{cht}$	$\ln x_{cht}$	$\ln x_{cht}$
$D_t^{2002} \times Gap_g$	0.066***	0.888***	0.871***
	(0.019)	(0.136)	(0.135)
$\log GDP_c \times D_t^{2002} \times Gap_g$		-0.091***	-0.090***
		(0.017)	(0.015)
HI_{cst}			-0.575***
			(0.041)
R^2	0.87	0.87	0.87
Observations	1,703,158	1,700,639	1,700,639
Country × Product FE	yes	yes	yes
Country × Year FE	yes	yes	yes

Notes: Table indicates the effect of Chinese import competition on the physical quantity of products shipped by other countries to the U.S. Dependent variable is the log quantity of products imported from all exporting countries except China. Independent variables are interaction of Gap and post-2002 period and triple interaction of Gap, post-2002 period and log of exporting country's GDP per capita. Other control variable is the Herfindahl index which controls for the number of exporting firms at each country, HS4-sector and time. Data span 1992 to 2005. Robust standard errors adjusted for clustering at country × HS8-product are shown in parentheses below the estimate values. All columns include country × HS10-product country × year fixed effects. ***, ** and * indicates statistical significance at 99%, 95% and 90% level, respectively.

2.2 Robustness

In this section, I first test the common trend assumption for DID specification in price and quantity regressions. Then I examine the sensitivity of empirical regularities found in Section 2.1 to change in duties that the U.S. charged different exporting countries. Finally, I check if the empirical facts can be outcomes of another possible explanation.

Parallel Trend Assumption. The most critical identifying assumption in difference-in-difference specifications is that control and treatment groups experienced identical time trends prior to implementation of intervention. In the context of DID regression for price and quantity responses presented in 2.1, it means to make sure that different product categories g had identical time trends in export price and quantity before 2002. To capture different time trends, I include product-year fixed effects (D_{gt}) in regressions. Results are displayed in the first two columns of Table 3. Apparently, DID ($D_t^{2002} \times Gap_g$) effect is picked up by product-year fixed effects. However, sign of triple difference term in price and quantity regressions verifies the same pattern across different exporting countries as documented before.

Change in Duties. One of the main concerns about the empirical facts is that they may not be the result of intensified competition but rather are derived because of change in duties that the U.S. collected from each exporting country over time. To control for this explanation, I included ad valorem equivalent of duties charged by the U.S. in each product h (10-digit HS code) sourced from country c at time t, tar_{cht}. This measure is constructed by dividing duty value by the total value of imports, v_{cht}. Columns 3 and 4 of Table 3 indicates the regressions. Results show while more duties increase export price and decrease export quantity, the differential response of countries to China's competition remain unchanged.

Shifting Exports toward Other Destinations. Another possible explanation for the quantity regression presented in Table 2 is that when exporting firms faced a fiercer competition in the U.S. market after 2002, they tried to reallocate their exports away from the U.S. market and toward other destinations such as European Union (EU) and Canada. Therefore, since rich countries are more flexible in transferring their exports across different locations, we observe that they cut more from

their quantity of shipment to the U.S. market and shift it toward EU and Canada markets. To assess the validity of this explanation, I use bilateral trade data from UN Comtrade and construct total export quantity of each exporting country c to EU countries and Canada in each 6-digit HS product[1] h' and call it $\ln EU\_CAN\_Exp_{ch't}$. I test the hypothesis by regressing $EU\_CAN\_Exp_{ch't}$ on a DID term $D_t^{2002} \times Gap_{g'}$ and a triple difference term $\log GDP_c \times D_t^{2002} \times Gap_{g'}$:

$$\begin{aligned} \ln EU\_CAN\_Exp_{ch't} =& \alpha_1 D_t^{2002} \times Gap_{g'} + \alpha_2 \log GDP_c \times D_t^{2002} \times Gap_{g'} \\ &+ \alpha_3 HI_{cst} + D_{ch'} + D_{ct} + \varepsilon_{ch't} \end{aligned} \tag{3}$$

where $Gap_{g'}$ is the average gap of 8-digit HS product categories within 6-digit HS code g'. Results are displayed in column 5 of Table 3. If the hypothesis is true, we should get a positive significant estimate for α_2 showing flexibility of rich countries in changing their export destinations. Although positive and significant estimate of α_1 confirms the idea that tougher competition in the U.S. market makes countries to re-allocate their exports to other destinations, estimate of α_2 is statistically equal to zero saying that there is no differential ability across countries in this export re-allocation. Column 6 is an extension of regression 3 in which I satisfy parallel trend assumption by adding product-year fixed effects ($D_{g't}$). This extension also verifies that there is no cross-country differences in export re-allocation.

[1]The most detailed product categories at which UN Comtrade records bilateral trade data is 6-digit HS code.

Table 3: Robustness Exercise

	$\ln p_{cht}$	$\ln x_{cht}$	$\ln p_{cht}$	$\ln x_{cht}$	$\ln EU\_CAN\_Exp_{ch't}$	$\ln EU\_CAN\_Exp_{ch't}$
$\log GDP_c \times D_t^{2002} \times Gap_g$	0.013**	-0.091***	0.013 **	-0.091***		
	(0.006)	(0.015)	(0.006)	(0.015)		
HI_{cst}	0.004	-0.334***	0.004	-0.333***		
	(0.019)	(0.039)	(0.018)	(0.039)		
tar_{cht}			0.045**	-0.106 *		
			(0.022)	(0.063)		
$D_t^{2002} \times Gap_{g'}$					0.350**	
					(0.172)	
$\log GDP_c \times D_t^{2002} \times Gap_{g'}$					0.026	0.019
					(0.019)	(0.015)
Country × Product FE (ch)	yes	yes	yes	yes	no	no
Country × Year FE (ct)	yes	yes	yes	yes	yes	yes
Product × Year FE (gt)	yes	yes	yes	yes	no	no
Country × Product FE (ch')	no	no	no	no	yes	yes
Product × Year FE ($g't$)	no	no	no	no	no	yes
R^2	0.93	0.89	0.93	0.89	0.86	0.91
Observations	1,692,077	1,692,077	1,692,077	1,692,077	975,713	973,450

Notes: Table indicates robustness results for empirical regularities documented in Tables 1 and 2. First and second columns reports results when parallel trend assumption is satisfied by including HS8-product × year fixed effects. Column 3 and 4 indicates robustness when explicitly accounting for country-product tariff changes over time. Column 5 displays result of DID regression of the log of total quantities exported from all exporting countries except China into EU countries and Canada on interaction of Gap (averaged at HS6 product level) and post-2002 period and triple interaction of Gap, post-2002 period and log of exporting country's GDP per capita. Country × HS6-product fixed effects are captured in 9-th row. Column 6 indicates the same regression results as column 5 while satisfying parallel trend assumption by including HS6-product × year fixed effects. Data span 1992 to 2005. Robust standard errors adjusted for clustering at country × HS8-product (HS6-product in columns 5 and 6) are shown in parentheses below the estimate values. ***, ** and * indicates statistical significance at 99%, 95% and 90% level, respectively.

3 The Model

The model is an extension to BEJK which incorporates quality as an endogenous choice. There are N countries indexed by $i \in \{1, ..., N\}$ which can export their products to each other. Consumers, sharing the same utility, consume goods to maximize their utility and provide labor force inealstically to the producers. Producers use labor force which is the only factor of production to make and then sell their products both domestically and in foreign markets.

In Section 3.1 and 3.2, I elaborate on the decision problems faced by consumers and producers, respectively. Section 3.3 explains the market structure. Section 3.4 solves for the partial equilibrium of the model and Section 3.5 discusses a special case. Finally, Section 3.6 derives a gravity equation which governs international flow of goods.

3.1 Consumers

The representative consumer in country n has a utility function which is a CES aggregate of continuum of goods indexed by $j \in [0, 1]$:

$$U_n = \left[\int (z_j^{\alpha} x_j)^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}} \tag{4}$$

where z_j and x_j are the quality and quantity of good j, respectively and α is the relative importance of quality. The optimal consumption of good j in country n is given by:

$$x_{nj} = E_n P_n^{\sigma-1} z_j^{\alpha(\sigma-1)} p_j^{-\sigma} \tag{5}$$

where p_j is the price of good j, P_n is country n's aggregate price index and E_n is the total expenditure in country n.

The indirect utility u_j that a consumer derives from good j is obtained by substituting optimal consumption of x_j back into the utility 4 which would be proportional to:

$$u_j \propto \frac{z_j^{\alpha}}{p_j} \tag{6}$$

3.2 Producers

On the production side, I depart from the current standard in the literature and assume two dimensions for the comparative advantage of countries: Countries are heterogeneous not only in the technology frontiers for physical production but also in their capability for making high quality goods[2].

Following BEJK, the joint efficiency distribution of the best and the second best producers (φ_1 and φ_2, respectively) in country i obeys bivariate Fréchet distribution[3]:

$$F_i(\varphi_1, \varphi_2) = [1 + T_i(\varphi_2^{-\theta} - \varphi_1^{-\theta})] \exp(-T_i \varphi_2^{-\theta}) \tag{7}$$

where $0 < \varphi_2 < \varphi_1$. $T_i(> 0)$ captures the absolute advantage of country i in physical production and $\theta(> 1)$ measures the heterogeneity of efficiencies.

Quality can increase the cost of production in two ways: First, the firm needs to incorporate more production inputs (here, labor) to produce the same amount of output but at the higher level of quality. Therefore, quality raises the marginal cost. Many papers, among which is Feenstra and Romalis (2014), Fan et al. (2017) and Eaton and Fieler (2017), use this approach to account for the role of quality in the cost structure. Second, there is a fixed cost associated with quality upgrading: reflecting for example more advanced technology, more product design services, a better distribution network, more advertisement, etc. that might be associated with higher quality. Some papers, including Kugler and Verhoogen (2012) and Eslava et al. (2018), consider a fixed cost for quality upgrading. In this paper, both approaches are incorporated and marginal and fixed costs are increasing in quality.

Specifically, the total cost that a typical firm with efficiency φ in country i incurs in order to deliver x units of output with quality level z to country n is given by:

$$C_{in}(x, z; \varphi) = \frac{w_i d_{in} z^{\gamma}}{\varphi} x + w_i z^{\beta_i} \tag{8}$$

where w_i is the prevalent wage in country i and d_{in} is the ad valorem trade cost showing the amount of output that needs to be shipped from source i in order to

[2] Hallak and Sivadasan (2013) also differentiate between two types of abilities but at the firm level: ability in producing goods at lower marginal cost (process productivity) and ability in producing goods at higher quality level (product productivity).

[3] See Eaton and Kortum (2005), Chapter 4, for the micro-foundation of this distribution.

deliver one unit to destination n. The comparative advantage of country i in producing high quality goods is reflected in β_i.β_i can be interpreted as the capability of country i in upgrading quality: the higher β_i, the more costly for firms in country i to make high quality goods.

3.3 Market Structure

For each good, there are many potential producers from all over the world who are perfect substitutes for each other. They engage in a two-dimensional Bertrand competition in which they not only choose the price but also the quality of output. At the end, the one who can provide the consumer with the lowest quality-adjusted price, will be the only seller of that good in the market.

3.4 Partial Equilibrium

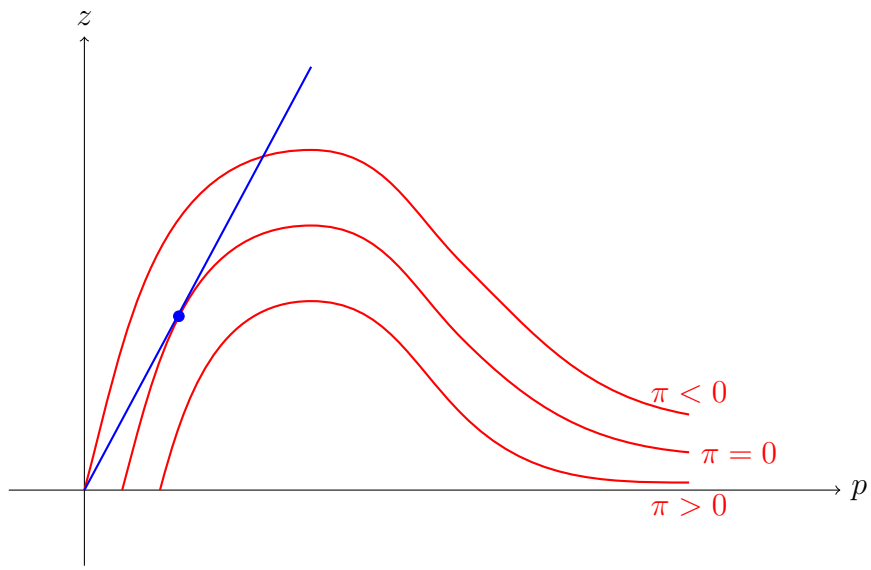
This section fixes the destination country, which is called Home, and characterizes trade equilibrium in the Home country while taking wages and total incomes as given. The goal is to focus on import competition effects in the Home country to: (i) analyze export price and quality decisions of the firms serving the Home market and (ii) investigate how they would react if the Home market becomes more competitive. Therefore, I can drop destination subscript n while remembering that variable x_i should be recognized as variable x when it is sourced from country i and goes to the Home country. For example, d_i means the iceberg trade cost of shipping goods from source i to the Home.

To characterize the Bertrand equilibrium, two steps are in order. First, I need to figure out who wins the competition and second, given the identity of the winner, I have to derive the price and quality at which the winner sells its product.

For the first step, notice that since producers are perfect substitutes, there will be one active seller for each good in the market and the consumer buys that good only from the firm which can offer the lowest quality-adjusted price or the highest utility as indicated in 6. Therefore, the winner of Bertrand competition is the firm providing the highest utility subject to earning non-negative profit.

Consider a producer with efficiency φ from country i. The highest utility, $U_i(\varphi)$, that it can deliver to Home's consumers subject to earning non-negative profit,

Figure 2: Utility Maximization Problem



solves the following maximization problem:

$$\begin{aligned} \max_{z,p} \quad & U_i(\varphi) = \frac{z^{\alpha}}{p} \\ \text{s.t.} \quad & Bz^{\alpha(\sigma-1)}p^{1-\sigma} \geq \frac{w_i d_i z^{\gamma}}{\varphi} Bz^{\sigma-1}p^{-\sigma} + w_i z^{\beta_i} \end{aligned} \tag{9}$$

where $B = EP^{\sigma-1}$ captures Home's aggregate demand. The left hand side of the budget constrain is the total revenue of the firm and the right hand side is the total cost. Figure 2 illustrates graphical representation of this problem. It shows the decision space of a firm where quality is on the vertical and price is on the horizontal axis. The objective function is the slope of the blue ray which indicates quality divided by price. Iso-profit curves of the firm are shown in red and as we move the curve to the right and down, the firm earns a higher profit. So as the firm increases the utility of consumer by offering higher quality and lower price (i.e. rotating blue ray counter clock wise), its profit decreases. Therefore, maximum utility that firm can afford is attained at the point where the blue ray is tangent to the zero-profit curve.

Equivalently, the analytical solution to this utility-maximization problem is:

$$U_i(\varphi) = (\lambda_i B)^{\frac{\lambda_i}{1-(\sigma-1)\lambda_i}} \left[\frac{1}{(1+\lambda_i)w_i}\right]^{\frac{1+\lambda_i}{1-(\sigma-1)\lambda_i}} d_i^{\frac{-1}{1-(\sigma-1)\lambda_i}} \varphi^{\frac{1}{1-(\sigma-1)\lambda_i}} \tag{10}$$
$$= A_i \varphi^{\frac{1}{1-(\sigma-1)\lambda_i}}$$

where $\lambda_i = \frac{\alpha-\gamma}{\beta_i}$ and $A_i = (\lambda_i B)^{\frac{\lambda_i}{1-(\sigma-1)\lambda_i}} ((1+\lambda_i)w_i)^{\frac{-1-\lambda_i}{1-(\sigma-1)\lambda_i}} d_i^{\frac{-1}{1-(\sigma-1)\lambda_i}}$. Sufficient conditions for solution 10 to maximize problem 9 are $\alpha > \gamma$ and $\lambda_i(\sigma-1) < 1$. Note that there are two components contributing to $U_i(\varphi)$: country-specific components w_i, λ_i and d_i which are collected into A_i and a firm specific component φ. Denoting the highest and the second highest efficiencies in country i by φ_{1i} and φ_{2i}, the highest and the second highest utility that can be provided to Home by country i would be $U_{1i} = U_i(\varphi_{1i})$ and $U_{2i} = U_i(\varphi_{2i})$, respectively. Since φ_{1i} and φ_{2i} are obeying the bivariate Fréchet distribution 7, I can derive the joint distribution of U_{1i} and U_{2i} as:

$$G_i(u_1, u_2) = \Pr(U_{1i} \leq u_1, U_{2i} \leq u_2) = [1 + \Phi_i(u_2^{-\theta_i} - u_1^{-\theta_i})] \exp(-\Phi_i u_2^{-\theta_i}) \tag{11}$$

where $\Phi_i = T_i A_i^{\theta_i}$ governs the average size of utility coming from i and $\theta_i = \theta(1 - \lambda_i(\sigma-1))$ governs its heterogeneity. Consequently, the distribution of the highest utility that can be sourced from i is:

$$G_i(u) = \Pr(U_{1i} \leq u) = \exp(-\Phi_i u^{-\theta_i}) \tag{12}$$

Now, denote the highest and the second highest utility that can be delivered to Home from all over the world by U_1 and U_2, respectively. Then

$$U_1 = \max_i U_{1i} \tag{13}$$
$$U_2 = \min\{U_{2i^*}, \min_{i \neq i^*} U_{1i}\}$$

where country $i^* = \arg\max_i U_{1i}$ is the nationality of the winner of Bertrand competition. Using the probabilistic formulation of the highest utility from each source country, I can derive the probability that a firm from a given country be the active seller for a particular good.

Proposition 1. *Probability that a firm from country i be the supplier for a particular good in the Home market is:*

$$\pi_i = \Phi_i \theta_i \int_0^\infty u^{-\theta_i - 1} \exp(-\sum_j \Phi_j u^{-\theta_j}) du \tag{14}$$

Proof. See Appendix A.1. □

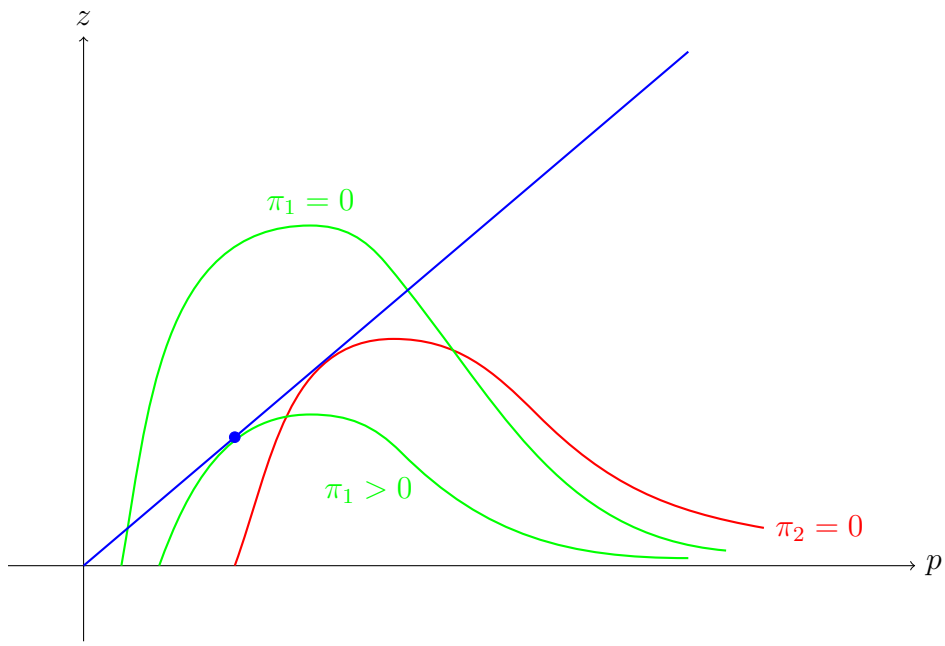
In the second step to characterize the Bertrand equilibrium, given the identity of winner (i.e. best producer), I need to determine what price and quality the winner offers in the market. Suppose that the best producer is a monopolist. It chooses the price p_m and quality z_m (where m stands for "monopolist") which together provide utility $U_m \propto z_m^\alpha / p_m$ to the consumer. Now, in the Bertrand competition, the best producer is limited by the second best producer as long as $U_2 > U_m$. In this case, the objective of the best producer is to maximize its profit conditional on providing utility which is weakly greater than U_2 in order to remain the active seller in the market. This means that it needs to lower the price and raise the quality relative to the monopolist's choice, up to the point that keeps the second best producer out of the market. In other words, it solves this profit-maximization problem:

$$\begin{aligned} \max_{p,z} \quad & \pi_1 \\ \text{s.t.} \quad & \frac{z^\alpha}{p} \geq U_2 \end{aligned} \tag{15}$$

where I subscripted the best and the second-best producers by 1 and 2, respectively. It can be verified that the monopolist-delivered utility U_m is fraction $\delta = [(\frac{\sigma-1}{\sigma})(1+\lambda)]^{\frac{1+\lambda}{1-\lambda(\sigma-1)}}$ of U_1 where the sufficient condition $\lambda(\sigma-1) < 1$ for problem 9 implies $\delta < 1$. So if $U_2 > \delta U_1$, then the best producer is bounded by the second-best producer and needs to solve problem 15. Otherwise, it would be a monopolist in the market and decides about its price and quality accordingly.

Figure 3 illustrates graphical representation of problem 15. The green and red curves represent the iso-profit curves of the best and the second-best producers, respectively. Blue ray's slope is the maximum utility that the second-best firm can deliver subject to earning non-negative profit. This gives the utility that the best producer is bounded to provide. So the equilibrium point is where the best producer's iso-profit curve becomes tangent to the blue ray. Equivalently, analytical solution for the equilibrium price and quality is:

Figure 3: Profit Maximization Problem



$$p = \begin{cases} \left[\dfrac{EP^{\sigma-1}(\alpha-\gamma)}{w_1(\beta_1+\alpha-\gamma)}\right]^{\frac{\alpha}{\beta_1}} \dfrac{1}{U_2^{\frac{\beta_1+(\alpha-\gamma)-\alpha\sigma}{\beta_1+\alpha-\gamma}} U_1^{\frac{\alpha(\beta_1-(\sigma-1)(\alpha-\gamma))}{\beta_1(\beta_1+\alpha-\gamma)}}} & \text{if} \quad U_2 > \delta_1 U_1 \\ p_m & \text{if} \quad U_2 < \delta_1 U_1 \end{cases} \tag{16}$$

$$z = \begin{cases} \left[\dfrac{EP^{\sigma-1}(\alpha-\gamma)}{w_1(\beta_1+\alpha-\gamma)}\right]^{\frac{1}{\beta_1}} \dfrac{U_2^{\frac{\sigma}{\beta_1+\alpha-\gamma}}}{U_1^{\frac{\beta_1-(\sigma-1)(\alpha-\gamma)}{\beta_1(\beta_1+\alpha-\gamma)}}} & \text{if} \quad U_2 > \delta_1 U_1 \\ z_m & \text{if} \quad U_2 < \delta_1 U_1 \end{cases} \tag{17}$$

Now let's investigate the effect of competition on the equilibrium price and quality. In this model, competition acts through two channels. The first channel stems from the head-to-head nature of competition that firms are engaged in. This channel implies that the incumbent firm is directly responding to the competition induced from the second-best firm. I call it the *direct* effect and measure its size by U_2. The second channel acts through the aggregate price P in the sense that more intense competition reduces the aggregate price and the market share of each firm which in turn affects firm's incentives when deciding about the price and quality. This is the standard effect of competition in monopolistically competitive markets which I call it the *indirect* effect.

To fix the idea, assume that the U.S. is the Home market and consider the comparative statics that China gets access to the WTO. Following this accession, there would be a huge amount of Chinese firms entering into the U.S. market which makes the competition tougher for the incumbents. In the context of the model, this entry translates to: (i) an increase in U_2 because the pool of potential producers expands and consequently the second highest utility that can be delivered out of this pool would be higher than before (direct effect), and (ii) a decrease in aggregate price index P (indirect effect).

As for the direct effect, the incumbent firm now faces a stronger rival and therefore has to provide higher utility to the consumer in order to remain in the market. Inspecting 16 and 17 shows that it would do so by adjusting on both margins of price and quality in response to an increase in competition (i.e. higher U_2): It needs to both upgrade the quality and reduce the price. However, how much of this response is on the price margin and how much of it is on the quality margin, depends on the capability of the exporting country in producing high quality goods (i.e. β_1). Incumbent firms from developed countries have lower fixed cost of upgrading quality, so their main response would be upgrading quality. This effect is captured by the elasticity of price and quality with respect to competition. Price elasticity of competition is $\frac{\beta_1+(\alpha-\gamma)-\alpha\sigma}{\beta_1+(\alpha-\gamma)}$ and quality elasticity of competition is $\frac{\sigma}{\beta_1+(\alpha-\gamma)}$. As we move from less- to more-developed countries, β decreases and so price elasticity of competition decreases. This means that the incumbent firms from less-developed countries reacts to the competition mainly by cutting down prices and therefore price response is larger for these countries relative to more-developed countries.

As for the indirect effect, reduction in the aggregate price and market share makes the firm cut down its markup. Moreover, the firm would also downgrade its quality because shrinkage in the market share reduces the marginal benefit of providing higher quality. This captures the Schumpeterian effect in which competition discourages innovation (here, quality upgrading).

Direct and indirect effects both lead the firm to reduce its price but they have the opposite impacts on the quality. In relation to the literature of competition and innovation, I have developed a highly tractable and static model that nests both types of innovation response to competition. The following corollary summarizes these results.

Corollary 1. *Firm responds to Head-to-Head import competition both directly and indirectly. Direct effect acts through the potential rival's threat and makes the firm increase quality and decrease price. More capable firms (with lower β) respond more on the quality margin rather than the price margin and vice versa for less capable firms. Indirect effect acts through market share and makes the firm decrease both price and quality.*

On top of that, the model implies two other properties that have been already verified in the literature.

Corollary 2. *Everything else equal, firms from distant countries ship higher quality goods to the Home markets.*

In the literature, the fact that firms ship higher-quality products to farther distance is usually generated by assuming specific trade cost. However, in this model, head-to-head competition helps to generate it without resort to specific trade cost: in the Bertrand competition, the quality-adjusted priced and consequently the total revenue of the best firm is completely disciplined by the second-best firm. Therefore, profit maximization problem faced by a firm reduces to a cost minimization problem. An increase in the trade cost, makes the shipment of each unit of output costlier. Therefore, firms try to avoid the increased trade cost by shifting the cost structure toward the fixed cost part and providing higher quality rather than producing more output.

Corollary 3. *Everything else equal, firms ship higher quality goods to larger economies.*

This corollary comes from the fact that the cost of quality upgrading is paid in the form of fixed cost. Therefore, there is an economy of scale in the quality provision: If the destination market becomes larger (in terms of total income), any level of investment in quality upgrading results in more revenue. This gives the firm more incentive to incur the cost and improve quality. This corollary can serve as a driving force of the fact pointed by Manova and Zhang (2012), that Chinese firms who charge higher prices in bigger markets.

3.5 Special Case

Although the main mechanisms of the model are described in Section 3.4, it is still useful to see a simple special case in which I can analytically investigate the quality

upgrading response of firms to intensified import competition in the Home market. This special case is constructed by setting the elasticity of substitution σ to one which means assuming Cobb-Douglas utility function over goods.

In this case, the average utility coming from country i becomes $\Phi_i = T_i A_i^{\theta}$ where $A_i = (\lambda_i B)^{\lambda_i} \left((1+\lambda_i)w_i\right)^{-1-\lambda_i} d_i^{-1}$. Notice that the dispersion of utility would be identical for all source countries, i.e. $\theta_i = \theta$, when $\sigma = 1$. While this assumption ($\sigma = 1$) removes the difference between dispersion of utilities coming from different source countries, it makes the model tractable in the sense that I can derive closed form solutions for trade shares and the distribution of equilibrium quality.

Corollary 4. *Under the Cobb-Douglas utility, the equilibrium price and quality that source country i provides in the Home market is:*

$$p_i = \frac{\bar{p}_i}{U_2^{1-\frac{\alpha}{\beta_i+\alpha-\gamma}} U_1^{\frac{\alpha}{\beta_i+\alpha-\gamma}}} \tag{18}$$

$$z_i = \bar{z}_i \left(\frac{U_2}{U_1}\right)^{\frac{1}{\beta_i+\alpha-\gamma}} \tag{19}$$

where $\bar{p}_i = \left[\frac{E(\alpha-\gamma)}{w_i(\beta_i+\alpha-\gamma)}\right]^{\frac{\alpha}{\beta_i}}$ *and* $\bar{z}_i = \left[\frac{E(\alpha-\gamma)}{w_i(\beta_i+\alpha-\gamma)}\right]^{\frac{1}{\beta_i}}$ *can be interpreted as the average price and quality of goods sourced from country i.*

Proof. Equations can be derived simply by plugging $\sigma = 1$ into equations 16 and 17. □

Notice that in this special case, best producer is always bounded by the second best producer because the utility it delivers as a monopolist is zero (by choosing $p = \infty$ and $z = 0$) which is always less than the second-highest utility.

Proposition 2. *Under the Cobb-Douglas utility, trade share of country i in the Home market is identical to the probability that a firm from country i be the supplier for a particular good in the Home market which is equal to:*

$$s_i = \pi_i = \frac{\Phi_i}{\Phi} \tag{20}$$

where $\Phi = \sum_j \Phi_j$.

Proof. See Appendix A.2. □

Proposition 3. *Under the Cobb-Douglas utility, the ratio of the second-highest to the highest utility for a good sourced from country i is:*

$$\Pr\left(\frac{U_2}{U_1} \leq x \mid i\right) = x^{\theta}, \qquad 0 < x < 1 \tag{21}$$

Proof. See Appendix A.3. □

Now using this Proposition and the expression for the equilibrium quality 19, I can derive the quality distributions.

Proposition 4. *Under the Cobb-Douglas utility:*
(i). The quality distribution of products exported by country i to the Home market is:

$$H_i(\zeta) = \Pr(z_i \leq \zeta | i) = \left(\frac{\zeta}{\bar{z}_i}\right)^{\theta(\beta_i+\alpha-\gamma)} \tag{22}$$

(ii). The quality distribution of all products sold in the Home market is:

$$H(\zeta) = \Pr(z \leq \zeta) = \sum_{i=1}^{n} \pi_i \left(\frac{\zeta}{\bar{z}_i}\right)^{\theta(\beta_i+\alpha-\gamma)} \tag{23}$$

Proof. The proof immediately follows combining equilibrium quality 19 and Proposition 3. □

Suppose the trade cost of country i toward the Home country, d_i, decreases. The distribution of quality conditional on the nationality of the exporter will remain unchanged. This fact becomes clear when inspecting 19: consider an exporting country $j \neq i$. Increased import from i, makes the competition tougher for j's firms. Two forces impact the quality distribution. On one hand, tougher competition makes less efficient firms exit the market. Remember that in the context of Bertrand competition, firms are cost minimizers because the quality-adjusted price which totally pins down a firm's revenue is determined by the second-best producer. Since efficiency can only reduce the variable cost, more efficient firms minimize the cost by shifting the cost structure toward the variable part rather than the fixed part. In other words, they charge lower prices and sell more in the market while reducing fixed cost by offering lower quality. So the exitors are the ones who used to provide higher quality. On the other hand, according to the direct effect of competition[4]

[4]Notice because of Cobb-Douglas utility, price index doesn't appear in 19 so there is no indirect or discouraging effect of competition on quality.

explained in Section 3.4, surviving firms will be induced to upgrade their quality. Therefore, two opposite-effect forces act on the quality of goods sourced from j. Assuming Fréchet distribution leads these effects to cancel out each other exactly, leaving the quality distribution of each country unchanged. Country i's quality distribution is influenced in a similar way: lower d_i not only makes competition for incumbent firms from i easier, but also leads to less efficient firms enter the market. The former downgrades the quality distribution of goods sourced from i and the latter upgrades it in a way that the net effect would be zero. This results is similar to the unresponsiveness of markups in BEJK when changing trade cost.

The next proposition summarizes the effect of intensified import competition on the quality of goods in the Home market.

Proposition 5. *Suppose the Home country reduces trade barriers toward country i, d_i, which induces import competition from country i. Denote the quality distribution of goods in the Home market before and after this change by $H_1(\zeta)$ and $H_2(\zeta)$, respectively. Moreover, denote the distribution function of quality provided by a surviving firm φ before and after the change by $h_1(\zeta|\varphi)$ and $h_2(\zeta|\varphi)$, respectively. Under the Cobb-Douglas utility function, if d_i decreases:*
(i). Surviving firm φ would stochastically increase its quality, i.e. $h_2(\zeta|\varphi) \succsim h_1(\zeta|\varphi)$.
(ii). If country i's quality is stochastically inferior to the average quality in the Home market (i.e $H(\zeta) \succsim H_i(\zeta)$), then the quality distribution of goods will be stochastically downgraded after country i's import competition, i.e $H_1(\zeta) \succsim H_2(\zeta)$.

Proof. See Appendix A.4. □

The intuition for part (i) is straight forward and is explained before. Basically, it is the increased competition effect in the Home market that makes firm φ upgrade its quality in order to survive the competition. Part (ii), however, needs more explanation. Consider a particular good produced by country $j \neq i$ before the fall in d_i. If country j remains the source of the good after the fall in d_i, then its quality will not change. This is because that selection to more efficient firms and quality upgrading of surviving firms cancel out their opposite effects on quality, leaving the quality distribution of country j unchanged (as explained in Proposition 4). However, in the case that a firm from country i replaces a firm from country j, it would provide it on average at a lower quality level because country i's endowment in quality

production is inferior to the average world's endowment. Then we would expect that the quality of goods, on average, become downgraded. In a nutshell, if the policy change shifts trade shares toward a country whose quality is below (above) the world's quality, then the quality distribution of goods sold in the Home market will be downgraded (upgraded).

3.6 Gravity

In this section, I derive a gravity equation which governs flow of goods between countries. There is a set of N countries. Each country i is populated with L_i units of labor and endowed with physical technology and quality capability parameters T_i and β_i, respectively. Preferences, cost functions and the market structure in each country is the same as described in the partial equilibrium setting. However, I extend the notation used in Section 3.4 to capture the bilateral nature of variables. For example, Φ_{in} is the average size of utility which is sourced from i and delivered to n:

$$\begin{aligned}
\Phi_{in} &= T_i A_{in}^{\theta_i} \\
A_{in} &= (\lambda_i E_n P_n^{\sigma-1})^{\frac{\lambda_i}{1-(\sigma-1)\lambda_i}} \left((1+\lambda_i)w_i\right)^{\frac{-1-\lambda_i}{1-(\sigma-1)\lambda_i}} d_{in}^{\frac{-1}{1-(\sigma-1)\lambda_i}} \\
\theta_i &= \theta(1-\lambda_i(\sigma-1))
\end{aligned}$$

International flow of goods is characterized by the gravity equation.

Corollary 5 (Gravity)**.** *Trade flow from country i to n, X_{in}, is given by:*

$$\begin{aligned}
X_{in} =& \frac{(1-\delta_i^{\theta_i})\Phi_{in}\int_0^\infty u^{\sigma-\theta_i-1}(\sum_j \Phi_{jn}\theta_j u^{-\theta_j-1})\exp(-\sum_j \Phi_{jn}u^{-\theta_j})du}{P_n^{1-\sigma}} X_n \\
&+ \frac{\delta_i^{\theta_i}\Phi_{in}\theta_i\int_0^\infty u^{\sigma-\theta_i-2}\exp(-\sum_j \Phi_{jn}u^{-\theta_j})du}{P_n^{1-\sigma}} X_n
\end{aligned} \tag{24}$$

where X_n is the total expenditure in destination n and P_n is the quality-adjusted price index in country n:

$$P_n^{1-\sigma} = \int_0^\infty (\sum_j (1-\delta_j^{\theta_j})\Phi_{jn} u^{\sigma-\theta_i-1})(\sum_j \Phi_{jn}\theta_j u^{-\theta_j-1}) \exp(-\sum_j \Phi_{jn} u^{-\theta_j}) du$$
$$+ \int_0^\infty (\sum_j \delta_j^{\theta_j} \Phi_{jn}\theta_j u^{\sigma-\theta_i-2}) \exp(-\sum_j \Phi_{jn} u^{-\theta_j}) du \tag{25}$$

and $\delta_i^{\theta_i} = [(\frac{\sigma-1}{\sigma})(1+\lambda_i)]^{\theta(1+\lambda_i)}$.

The reason that the expressions for X_{in} and P_n have two parts is that in the Bertrand competition, the threat of the second-best firm may not be limiting for the best firm. Accordingly, the first part of of the expressions pertain to the case when the best firm is bounded by the second-best and the second part pertain to the case when the best firm is indeed a monopolist. Gravity equation 24 doesn't deliver a closed form as in BEJK because θ_j is country-specific. However, in the special case of $\sigma = 1$, $\theta_j = \theta$ for all countries and closed form 20 can be derived.

4 Estimation

To estimate the model, first I need to specify a functional form for trade barriers. I use an exponential functional form:

$$d_{in} = \exp(a + a_{dist} Dist_{in} + a_{lang} + a_{border} + a_{agreement}) \tag{26}$$

where $Dist_{in}$ is the distance (in thousands of kilometers) between countries i and n. a_{lang}, a_{border}, $a_{agreement}$ are zero if countries i and n do not have a common official language, common border, trade agreement and an estimated parameter otherwise. Therefore, the set of parameters that need to be estimated is:

$$\Delta = \{\{T_i\}_{i=1}^n, \{\beta_i\}_{i=1}^n, a, a_{dist}, a_{lang}, a_{border}, a_{agreement}\}$$

where T_i and β_i are the technology and quality capability parameters governing the efficiency of country i in physical and quality production, respectively. Values for the rest of the parameters (α, γ, σ and θ) are borrowed from the literature. Specifically, I set $\gamma = 1.64$, the median value of quality elasticities of variable cost estimated by Feenstra and Romalis (2014) [5]. Values of trade elasticity and elasticity of substi-

[5] Actually, Feenstra and Romalis (2014) estimated $1/\gamma$ for 712 industries using bilateral trade data between all countries during 1984-2011. They reported the median value of $1/\gamma$ across industries to be 0.61.

tution are set to $\theta = 4$ and $\sigma = 2.25$ as estimated by Simonovska and Waugh (2014a) and Simonovska and Waugh (2014b), respectively. For α, the relative importance of quality in the utility function, I assume an arbitrary value of $\alpha = 2$ to satisfy the sufficient condition $\alpha > \gamma$ for the maximization of problem 9.

Data. I use data on bilateral trade flows and export prices (unit values) of 39 countries[6] in 2000 to estimate the model. Bilateral trade flow data are based on the UN Comtrade. Export price data are from Trade Unit Value (TUV) database compiled by Berthou and Emlinger (2011) and accessible through CEPII. I use CIF unit values at the 6-digit HS product level. Gravity data–distance between countries, common official languages, common borders and trade agreements– are compiled by Head et al. (2010). Finally, since the competition is not perfect in the model and firms earn profit, I can not use GDP per capita data for the wage variable. Instead, data on wages and total income of countries are taken from WIOD Socio-Economic Accounts (SEA) provided by Erumban et al. (2012).

Estimation Procedure. Set of parameters that are estimated is composed of $\boldsymbol{T} = \{T_i\}$, $\boldsymbol{\beta} = \{\beta_i\}$ and $\boldsymbol{a} = \{a, a_{dist}, a_{lang}, a_{border}, a_{agreement}\}$. I use balanced trade condition, average export price of each country and bilateral trade flows between countries to back out $\hat{\boldsymbol{T}}$, $\hat{\boldsymbol{\beta}}$ and $\hat{\boldsymbol{a}}$, respectively. The estimation procedure, inspired by Fieler (2011), is composed of three steps.

1. Given trade cost parameters $\boldsymbol{a}$ and quality capability parameters $\boldsymbol{\beta}$, I back out technology parameters $\boldsymbol{T}$ that make trade balanced for all countries. That is, I solve system of equations:

$$\sum_{n=1}^{N} X_{in} = X_i, \qquad \forall\, i = 1, 2, ..., N \tag{27}$$

   where X_i is the total GDP of country i.

   It should be noted that in steps 1 and 2, expressions are evaluated by numerical computation. For example and in step 1, X_{in} is obtained by numerical evaluation of integrals in 24, then adding all X_{in}'s across destinations and equating it to X_i.

2. Given trade cost parameters $\boldsymbol{a}$ and technology parameters $\boldsymbol{T}$, I back out quality capability parameters $\boldsymbol{\beta}$ by matching average export prices. That is, I derive

[6] See Appendix B for the list of countries.

the average export price of each country across all destinations implied by the model and then set it equal to the average export prices observed for each country in data:

$$
\begin{aligned}
E(\ln p_i) =& \frac{1}{\sum_{n=1}^{N} \pi_{in}} \sum_{n=1}^{N} \pi_{in} E(\ln p_{in} | i \ source) \\
=& \sum_{n=1}^{N} \pi_{in} \frac{\alpha}{\beta_i} \ln \left(\frac{E_n P_n^{\sigma-1}(\alpha-\gamma)}{w_i(\beta_i+\alpha-\gamma)} \right) - \sum_{n=1}^{N} \pi_{in} \left(1 - \frac{\sigma\alpha}{\beta_i+\alpha-\gamma} \right) E(\ln U_{2n} | i \ source) \\
& - \sum_{n=1}^{N} \pi_{in} \left(1 - \frac{\sigma(\alpha-\gamma)}{\beta_i+\alpha-\gamma} \right) E(\ln U_{1n} | i \ source) \\
=& \frac{1}{M_i} \sum_{n=1}^{N} \sum_{\omega} \ln p_{in}(\omega) \qquad \forall i = 1, ..., N
\end{aligned} \tag{28}
$$

where π_{in} is the probability that country i serves n, U_{1n} and U_{2n} are the highest and the second highest utilities that can be delivered to country n from all over the world. $p_{in}(\omega)$ is the observed unit value of product ω exported from i to n and M_i is the total number of 6-digit HS products that country i exported to the rest of the world in 2000.

3. Given a set of trade cost parameters $\boldsymbol{a}$, I iterate over steps 1 and 2 to converge to a solution for $\boldsymbol{T}$ and $\boldsymbol{\beta}$. Using this solution, I estimate trade cost parameters $\boldsymbol{a} = \{\hat{a}, \hat{a}_{dist}, \hat{a}_{lang}, \hat{a}_{border}, \hat{a}_{agreement}\}$ by NLLS estimation of gravity equation 24. Then, I feed the updated values of trade cost parameters into the first and second steps and repeat this procedure until estimated values converge to a solution.

Denoting the vector of country-level wages by $\boldsymbol{w} = \{w_i\}$, the vector of country-level GDP by $\boldsymbol{X} = \{X_i\}$ and the set of gravity data by $\boldsymbol{D}$, the entire estimation procedure can be summarized as finding a solution to the following constrained minimization problem:

$$
\begin{aligned}
\min_{\boldsymbol{T},\boldsymbol{\beta},\boldsymbol{a}} \quad & \sum_{i} \sum_{n} \left(X_{in}^{D} - X_{in}(\boldsymbol{T}, \boldsymbol{\beta}, \boldsymbol{a}; \boldsymbol{w}, \boldsymbol{X}, \boldsymbol{D}) \right)^2 \\
\text{s.t.} \quad & \begin{cases} \sum_{n=1}^{N} X_{in}(\boldsymbol{T}, \boldsymbol{\beta}, \boldsymbol{a}; \boldsymbol{w}, \boldsymbol{X}, \boldsymbol{D}) = X_i, & \forall\, i \\ E(\ln p_i(\boldsymbol{T}, \boldsymbol{\beta}, \boldsymbol{a}; \boldsymbol{w}, \boldsymbol{X}, \boldsymbol{D})) = \frac{1}{M_i} \sum_{n=1}^{N} \sum_{\omega} \ln p_{in}(\omega), & \forall\, i \end{cases}
\end{aligned}
$$

where X_{in}^D is the factual trade flow from country i to n, $p_{in}(\omega)$ is the observed unit value of product ω exported from i to n and M_i is the total number of products exported by country i to rest of the world.

Identification. The intuition for the identification of $\{T_i\}_{i=1}^n$ and $\{\beta_i\}_{i=1}^n$ is straightforward. Higher value of physical technology parameter, T_i, makes country i more productive and export more to the rest of the world. This drives up total income of country i. Therefore, holding other factors such as trade cost, quality capability, etc. fixed, T_i would be increasing in country i's GDP. On the other hand, lower value of quality cost β_i makes firms in country i to produce high-quality products and since quality is costly to produce, they charge higher prices. Therefore, lower β results in higher export prices.

5 Results

Figure 4 shows the result of estimation (detailed estimation results can be found in Appendix C) of technology parameters. Each circle in the graph is associated with a country. In the left panel log of technology parameter T is graphed versus log GDP per capita of countries and the right panel graphs quality cost parameter β against log GDP per capita. General pattern in Figure 4 indicates a strong relationship between development level of country and its efficiency in physical and quality production: rich countries are more advanced in technology (higher T) and more efficient in quality production (lower β). Table 4 indicates NLLS estimation of gravity parameters. The sign of parameters are as expected and the model can explain 65% of trade flows between countries.

Table 4: Estimated Values for Gravity Parameters

Parameter	a	a_{dist}	a_{border}	a_{lang}	$a_{agreement}$	R^2	Obs.
Estimated Value	1.6702	0.0113	-0.5223	-0.2933	-0.3246	0.65	1480
	(0.019)	(0.005)	(0.062)	(0.173)	(0.089)		

Notes: Table indicates the NLLS estimates of gravity parameters. Standard errors are reported in parentheses.

Now let's examine if the model can generate empirical regularities presented in Section 2 in Tables 1 and 2. I increase the import competition of China in the U.S.

Figure 4: Technology and Quality Cost Parameters

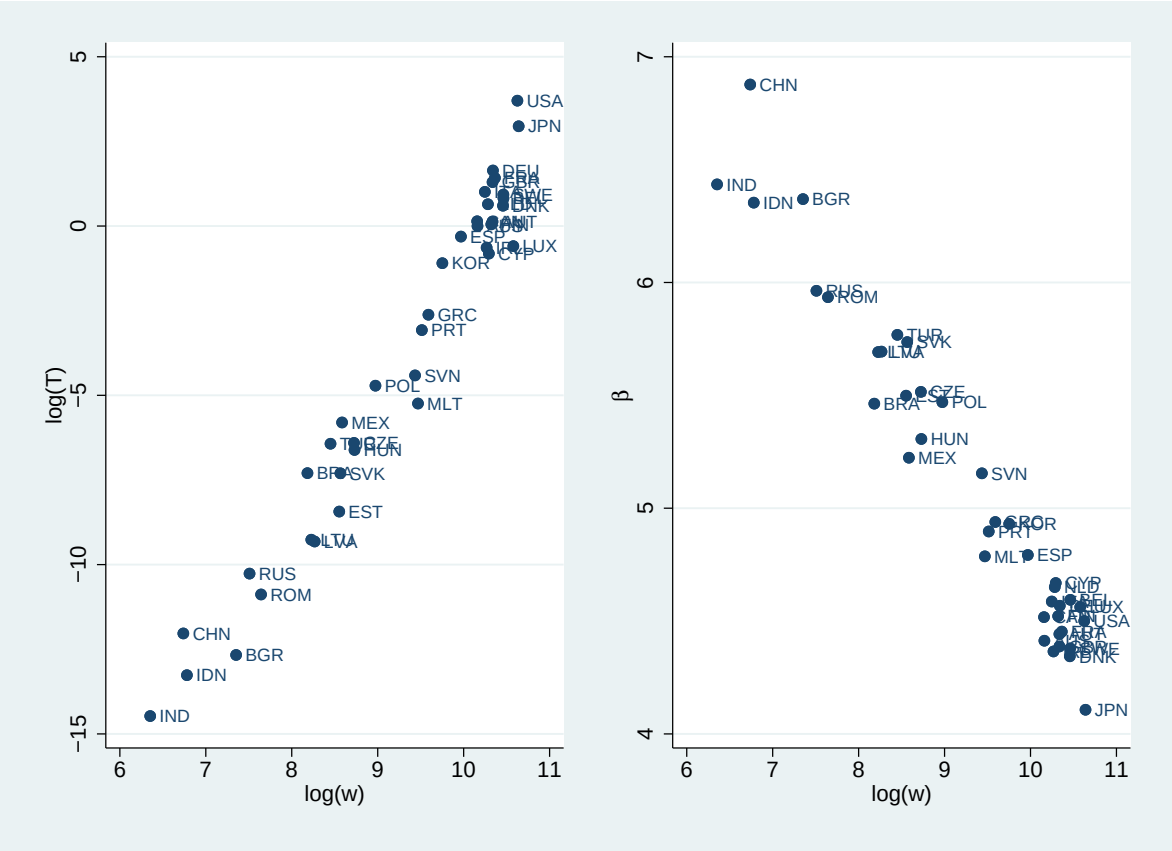


Table 5: Price and Quantity Regressions on Simulated Data

	Model with Quality		**Model without Quality**	
	$\ln p_{cht}$	$\ln x_{cht}$	$\ln p_{cht}$	$\ln x_{cht}$
D_t	-0.588***	0.525***	-0.054***	0.031
	(0.007)	(0.025)	(0.013)	(0.029)
$\log GDP_c \times D_t$	0.051***	-0.044***	-0.0017	0.003
	(0.0007)	(0.0023)	(0.001)	(0.002)
R^2	0.035	0.004	0.024	0.005
Observations	1,814,820	1,814,820	1,747,808	1,747,808

Note: Table indicates the effect of Chinese competition on simulated price and quantity. The first two columns indicate the results when accounting for the quality while the last two columns report the results when quality is missing. Simulation is done in two periods. In the first period, I simulate the model with the estimated values of parameters. In period two, in order to increase China's import competition, I decrease $d_{China-U.S.}$ to 1. Time dummy variable D_t captures the effect of competition and its interaction with log GDP per capita, let different countries respond to the competition differentially. Standard errors are reported in parenthesis.

market by removing trade barriers of Chinese producers to export to the U.S.. To track the response of other countries to the intensified Chinese competition, I simulate the model for two periods based on the estimated values of parameters in 2000. In the first period, trade costs are equal to what is estimated by the model in 2000. In the second period, I reduce $d_{China-U.S.}$ to 1 and re-simulate the model. Therefore, I would get a panel of price and quantity data for two periods and can run the same regressions as in Section 2. To show the importance of quality channel in generating the differential response of countries, I implement the same exercise when the quality channel is missing. More Specifically, first I close the quality channel and re-estimate the model using the procedure described in 4. Then using the new estimates of parameters, I simulate the model for two periods: in the first period trade costs are implied from trade cost parameters and in the second period, $d_{China-U.S.}$ is reduced to 1.

Table 5 indicates the results of regressions. The first two columns report the results when quality adjusts in response to the competition and the last two columns are for the model which misses the quality channel. In columns 1 and 3, price is projected on a time dummy variable (capturing the effect of competition) and its interaction with the log GDP per capita to differentiate between countries' responses.

Second and fourth columns run the same regression but with quantity as the dependent variable. Results indicate that the the model incorporating the quality channel generates the same pattern observed in the data: rich countries are less affected in terms of price but more affected in terms of quantity. Moreover, shutting down the quality response makes all the coefficients insignificant and thus eliminates this pattern.

For the intuition that how quality generates this heterogeneity in the response, notice that in the model, an increase in competition from perspective of the best firm is equivalent to make the second-best firm stronger or increasing the value of U_2. In the Bertrand competition, the quality-adjusted price of the best firm is totally disciplined by the second-best firm or U_2. If U_2 increases, best firm has to decrease its quality-adjusted price, otherwise it will lose the competition to the second-best. However, there are two ways to decrease the quality-adjusted price: decreasing (nominal) price, or increasing quality. Rich countries have comparative advantage in quality production, so they mainly reduce quality-adjusted price by upgrading quality and do not change the price significantly. On the other hand, poor countries will mainly react by reducing the price or equivalently, markup. Therefore, we observe that poor countries are more responsive to competition in terms of price, because this is the margin they are acting on. The response margin of rich countries is quality which we cannot observe and track in data, but that doesn't mean that rich countries do not respond to Chinese competition as much as poor countries.

To justify the quantity response or why poor countries are less affected in terms of quantity of shipment, consider profit maximization problem of an incumbent firm:

$$\max_{x,z} \qquad \pi = px - \frac{wd}{\varphi}x - wz^{\beta} \tag{29}$$

$$s.t. \qquad \begin{cases} xz \geq U_2 \\ p = B^{\frac{1}{\sigma}} z^{\frac{\sigma-1}{\sigma}} x^{\frac{-1}{\sigma}} \end{cases}$$

I set $\alpha = 1$ and $\gamma = 0$ to simplify the exposition. Problem 29 states that I can change decision variables of a firm from price and quality to quantity and quality using the demand function appeared as the second constraint. Substituting p from the demand function back into the objective function and imposing the fact that

constraint $xz \geq U_2$ is binding at the solution, objective function becomes:

$$\pi = B^{\frac{1}{\sigma}}(zx)^{\frac{\sigma-1}{\sigma}} - \frac{wd}{\varphi}x - wz^{\beta} = B^{\frac{1}{\sigma}}(U_2)^{\frac{\sigma-1}{\sigma}} - \frac{wd}{\varphi}x - wz^{\beta}$$

Therefore, revenue of an incumbent firm will be totally pinned down by the second-best firm. So the best firm is actually cost-minimizer and I can re-state its profit maximization problem as:

$$\begin{aligned} \min_{x,z} \quad & \frac{wd}{\varphi}x + wz^{\beta} \\ s.t. \quad & xz \geq U_2 \end{aligned}$$

Left panel in Figure 5 illustrates this cost minimization problem for representative firms from two different countries. Red and blue curves are the iso-cost curves of firms in quantity-quality space. Country 2 is more efficient in quality production than country 1, or $\beta_1 > \beta_2$, and it manifests itself in the red curve being more concave than the blue one. Moving iso-cost curve inward means providing more quantity and quality which increases total cost of a firm. Iso-utility curve U_2 demonstrates all the combination of quality-quantity which delivers utility level U_2. Therefore, cost-minimizing choice of quantity and quality conditional on providing utility U_2 is obtain by making iso-cost curve tangent to the iso-utility curve. Now assume that competition rises to $U_2' > U_2$. Firms have to re-optimize in order to deliver higher utility level. The result is illustrated in the right panel of Figure 5. Country 1's firm adjusts more on quantity side while country 2's firm mainly increases its quality.

This quantity response can be analytically confirmed if equilibrium value for quantity is derived. Using equilibrium expressions 16 and 17 for the price and quality and substituting them in the demand function, gives the equilibrium value for quantity:

$$x = \begin{cases} [EP^{\sigma-1}]^{1-\frac{\alpha}{\beta_1}} \left[\frac{(\alpha-\gamma)}{w_1(\beta_1+\alpha-\gamma)}\right]^{\frac{-\alpha}{\beta_1}} U_2^{\frac{\sigma(\beta_1-\gamma)}{\beta_1+\alpha-\gamma}} U_1^{\frac{\alpha(\beta_1-(\sigma-1)(\alpha-\gamma))}{\beta_1(\beta_1+\alpha-\gamma)}} & \text{if} \quad U_2 > \delta_1 U_1 \\ x_m & \text{if} \quad U_2 < \delta_1 U_1 \end{cases} \tag{30}$$

where again subscripts 1 and 2 refer to the best and the second-best producers. Direct effect of competition comes from an increase in U_2. Inspecting the above equation reveals that the power of U_2 is increasing in β. This means that the direct effect

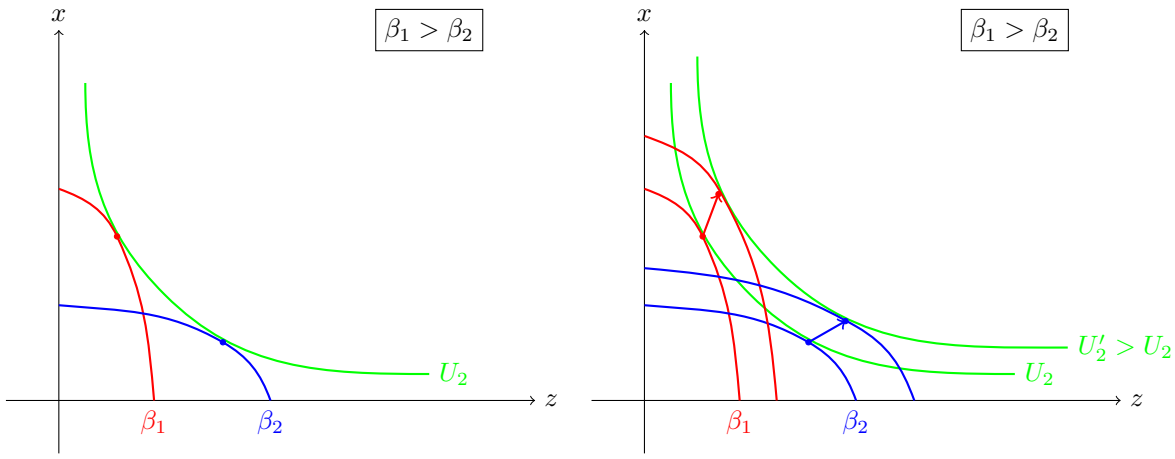


Figure 5: Differential Quantity Response

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of competition makes firms from rich countries to adjust in such a way that leads them to increase their quantity less.

To rationalize the pattern that Chinese competition makes rich countries reduce their quantity of shipment more, one needs to consider quantity response in extensive and intensive margins. At the extensive margin, China moves some firms from all other exporting countries out of the U.S. market. This results in a decrease in quantity of shipment from other countries to the U.S. market. At the intensive margin, incumbent firms which can survive Chinese competition, respond on quantity margins differentially. More specifically, firms from poor countries increase their quantity of shipment more than firms from rich countries. Therefore, the extensive margin effect is negative while the intensive margin effect is positive and stronger for poor countries. The outcome of these two opposite-direction effects appears in data to be negative or extensive margin dominates the intensive margin. However, since the counteracting intensive margin is stronger for poor countries, we observe that in aggregate they reduce their quantity of shipment less than rich countries.

Out-of-Sample Prediction. In order to see if the heterogeneous response of countries across two margins of quality and markup really matters in the real world, I assess model's performance in an out-of-sample prediction exercise. This experiment goes as follows: Given the estimated values $\{\hat{T}_i^{2000}\}_{i=1}^n$, $\{\hat{\beta}_i^{2000}\}_{i=1}^n$ and $\hat{a}^{2000}$, $\hat{a}_{dist}^{2000}$, $\hat{a}_{lang}^{2000}$, $\hat{a}_{border}^{2000}$, $\hat{a}_{agreement}^{2000}$ (superscript 2000 refers to the fact that the parameters are estimated using data in 2000), I simulate the model and generate the price and

quantity of each product that the U.S. has imported in 2000 in addition to identifying the source country for each product. After China's accession to WTO, model predicts that the U.S. market competition becomes tougher and other exporting countries respond to it heterogeneously in the sense that rich countries mainly upgrade their quality and poor countries mainly reduce markup. I assess this prediction by tracking how countries differentially changed their export prices and quantities in the U.S. market from 2000 to 2005. Year 2005 is chosen such that firms have enough time for quality upgrading. To capture the policy change from 2000 to 2005, I recalibrate the physical technology parameters $\{T_i\}_{i=1}^n$ and trade cost parameters to reflect the rise of China in the U.S. market. In other words, using $\{\hat{\beta}_i^{2000}\}_{i=1}^n$, $\{T_i\}_{i=1}^n$ and $\{a, a_{dist}, a_{lang}, a_{border}, a_{agreement}\}$ are re-estimated by making trade balanced for each country and matching trade flows in 2005. In the next step, I simulate the U.S. import market with data in 2005 and parameter values $\{\hat{T}_i^{2005}\}_{i=1}^n$, $\{\hat{\beta}_i^{2000}\}_{i=1}^n$ and $\{\hat{a}^{2005}, \hat{a}_{dist}^{2005}, \hat{a}_{lang}^{2005}, \hat{a}_{border}^{2005}, \hat{a}_{agreement}^{2005}\}$. Now I have two panel data sets: one is the real data and the other is generated by the model. In each data set, I can track how countries change their export prices and quantities to the U.S. from 2000 to 2005. To do so, I regress price and quantity values on a time dummy variable D_t (which is zero for 2000 and one for 2005) to capture the effect of the policy change and on the interaction of the time dummy and log GDP per capita to capture the response heterogeneity across exporting countries. For the sake of comparison, the same out-of-sample prediction exercise is implemented on the model which doesn't incorporate the endogenous choice of quality.

Table 6 indicates the results. For each model/data, the first and second columns illustrate the regression of price and quantity, respectively. Comparing column one with three and two with four, reveals that the model with quality adjustment has a good performance in predicting price and quantity responses. Although the model is highly stylized and has abstracted from many other mechanisms in the real world, it generates the observed heterogeneity in response of price and quantity to the increased competition from 2000 to 2005 relatively well. Confirming the prediction of the model, both data and simulation regressions indicate that poor countries responded to competition by reducing their price more while rich countries cut down more from their quantity of shipment. On the other side, the model without the endogenous choice of quality can not match the observed pattern of data: all the coefficients are insignificant. Neither the overall effect of competition on price and

Table 6: Out-of-Sample Prediction

	Data		**Model with Quality**		**Model without Quality**	
	$\ln p_{cht}$	$\ln x_{cht}$	$\ln p_{cht}$	$\ln x_{cht}$	$\ln p_{cht}$	$\ln x_{cht}$
D_t	-2.89***	5.19***	-1.65***	3.04***	-0.022	0.050
	(0.026)	(0.06)	(0.05)	(0.19)	(0.044)	(0.098)
$\log GDP_c \times D_t$	0.313***	-0.544***	0.163 ***	-0.320***	0.002	-0.005
	(0.003)	(0.006)	(0.005)	(0.02)	(0.004)	(0.01)
R^2	0.05	0.02	0.15	0.10	0	0
Observations	286,003	286,003	6,022	6,022	6,640	6,640

Note: Table compares two models' performances in out-of-sample prediction. Columns 1 and 2 indicate the price and quantity response to the rising import competition from 2000 to 2005 in the real data. Columns 3-4 and 5-6 indicate what the models with and without quality predicts for the same responses, respectively. Price and quantity of product h exported by country c at time t are denoted by p_{cht} and x_{cht}, respectively. Dummy variable D_t is zero for year 2000 and one for year 2005. $\log GDP_c$ is the log GDP per capita for exporting country c. Standard errors are indicated in parentheses. *** indicates statistical significance at 99% level. Standard errors are reported in parenthesis.

quantity nor its heterogeneity across countries can be explained by this model.

6 Counterfactuals

Two types of counterfactual are conducted in this section. First, I examine the importance of quality channel when a country assesses the welfare implication of liberalizing trade with its partners. Secondly, I investigate the effect of economy's size on the gains from trade.

6.1 Role of Quality

Consider a country, such as U.S., aims to liberalize trade with one of its trading partners. One natural question would be which country is the most beneficial country to liberalize trade with. To answer this question, I conduct two experiments. In the first experiment, I use the calibrated model proposed in this paper to calculate how much gain the U.S. receives from removing trade barriers with each of its partners.

This is done by setting $d_{i,U.S.} = 1$ for each source country i separately and measure the fall in the U.S.'s (quality-adjusted) price index. In the second experiment, I close the quality channel, re-estimate the model and implement the same exercise. Then welfare gains are compared across the two models.

Figure 6: Gains from Trade: Quality vs. No Quality

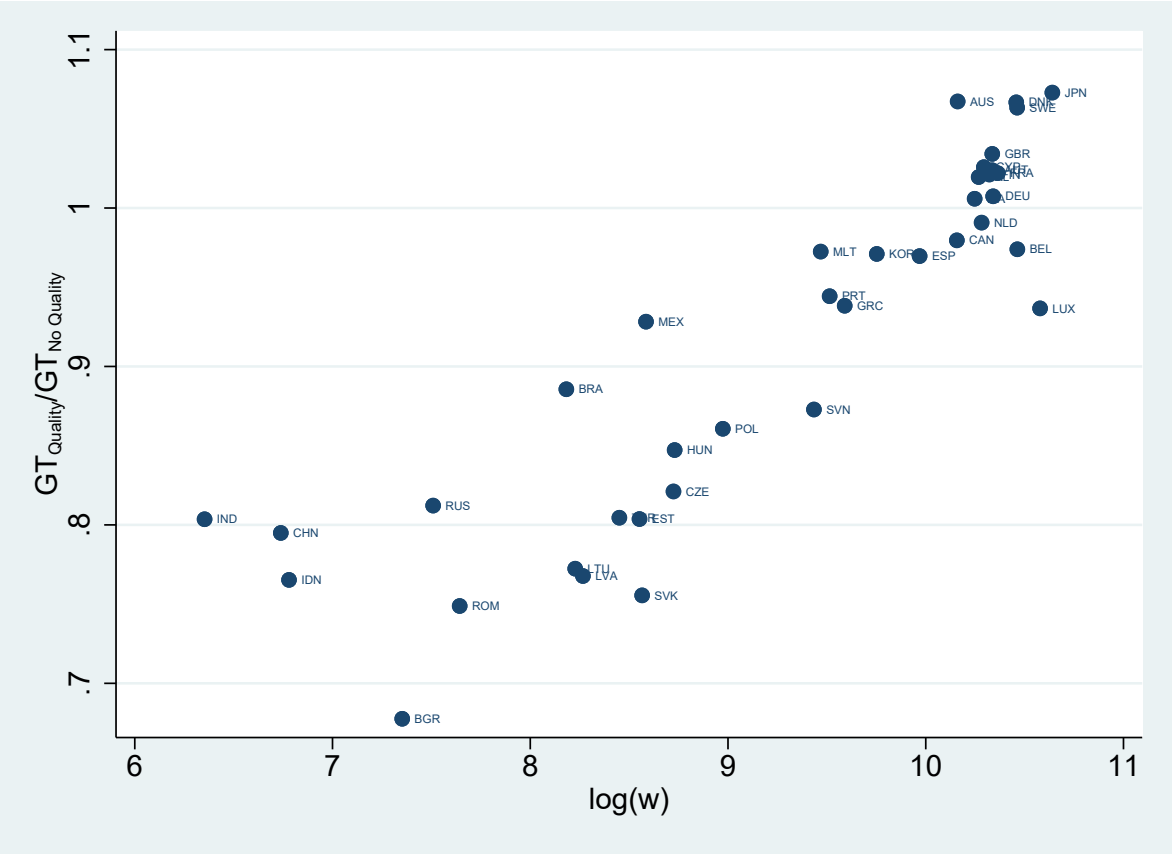


Figure 6 illustrates the comparison results. Horizontal axis shows the log GDP per capita of U.S. trading partners. Vertical axis shows the ratio of the gains from trade when quality channel is working relative to the case when quality channel is missing. Each dot in the figure corresponds to one U.S.'s partner and indicates the welfare implication of liberalizing trade with that partner only. Counterfactual results indicate that ignoring the quality channel leads to mis-measurement of the gains from trade. Specifically, the gains from trade with poor countries are over-estimated and the gains from trade with rich countries are under-estimated. This pattern arises because there are two sources for comparative advantage: one in

physical efficiency and the other in quality capability. Ignoring the quality capability leads one to over-estimate the competitiveness of poor countries (which are not efficient in quality production) relative to rich countries. On the other side, quality capability is a part of rich countries' competitiveness and without it, one would under-estimate the gains of trade with them.

6.2 Role of Economy's Size

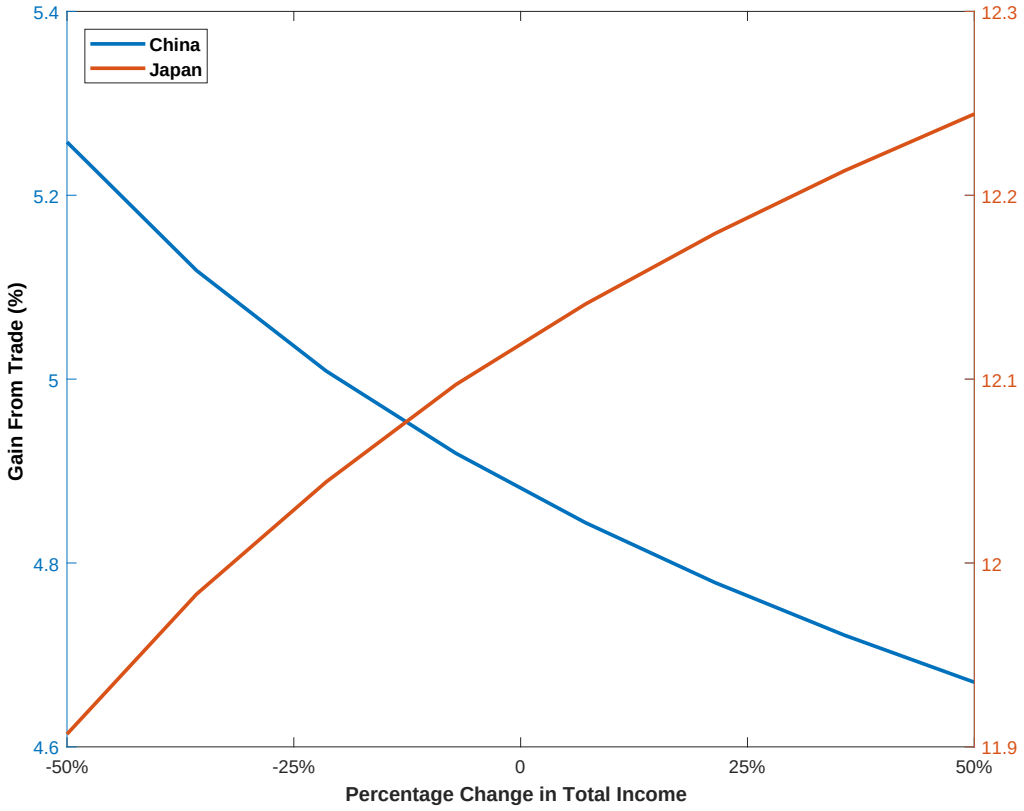
In this counterfactual experiment, I ask what is the role of economy's size in the gains from trade. The nature of the experiment is similar to the previous ones except that in this experiment, I only consider two of U.S.'s partners, namely "China" and "Japan", and remove their trade barriers. China is chosen as a representative of low-quality countries and Japan as a representative of high-quality countries.

Figure 7 illustrates the result of this counterfactual experiment. Horizontal axis shows changes (in percentage) in the U.S. total income. Vertical axis shows percentage drop in the U.S.'s quality-adjusted price index. The blue line indicates how much the U.S. gains by making trade free with China at each income level. The red line indicates similar results for Japan. The interesting result is that as the U.S. economy grows, the welfare gains of free trade with Japan increases while those of China decreases. This is the effect of economy of scale in quality. Because of the fixed costs for quality upgrading, there is an economy of scale in quality in the sense that selling in bigger markets gives firm more incentive to upgrade the quality. Now as the U.S. market becomes bigger, there will be more room for economy of scale in quality. Therefore, quality upgrading becomes more profitable and so firms with efficient technology in quality production can exploit this opportunity better than others. In other words, increasing the market size contributes to the competitiveness of countries that are efficient in quality production such as Japan relative to others such as China. As the U.S. economy grows, this effect makes it more desirable to engage in free trade with quality-capable countries.

7 Conclusion

This paper introduces a unifying model which can explain a firm's response on both margins of quality and markup to an intensified import competition. The unifying

Figure 7: Evolution of Gains from Trade as the Economy Grows



feature of the model is important in order to explain differential response of exporting countries to the U.S. market when the competition was intensified after China's accession to WTO: rich countries cut down the price less than poor countries, while reduced their shipment to the U.S. market more. Moreover, the quality channel turns out to be quantitatively important when a country evaluates the welfare effects of liberalizing trade with its partners.

The model considers a Ricardian trade framework with an endogenous choice of quality where firms are engaged in a head-to-head competition. Countries are not only heterogeneous in terms of physical productivity, but also in their capability to produce high quality outputs. Estimation results indicate that rich countries are more productive in both physical and quality productivity. After an increased import competition in the U.S. market, the model predicts that firms located in rich

countries mainly upgrade their quality while firms from poor countries mainly decide to reduce their markups. This pattern of response can generate the observed heterogeneous response of countries in terms of price and quantity which can not be explained by the standard models of trade. Moreover, incorporating the quality channel improves the out-of-sample performance of the model in predicting price and quantity responses. Counterfactual experiment reveals that as the U.S. economy grows, it benefits more from free trade with quality-capable countries than with countries which are less capable.

This paper also implies an avenue for future research. As mentioned earlier, import competition can result in both quality upgrading and markup reduction. But these two margins have different welfare implications for different income groups. Combining the two-dimensional adjustment model proposed in this paper with a preference which is non-homothetic in quality, one can measure the welfare implication of import competition for different income groups which is a key question for policy makers.

References

Aghion, Philippe, Antonin Bergeaud, Matthieu Lequien, and Marc J Melitz, "The Impact of Exports on Innovation: Theory and Evidence," Technical Report, National Bureau of Economic Research 2018.

_ , Nick Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt, "Competition and Innovation: an Inverted-U Relationship," *The Quarterly Journal of Economics*, 2005, *120* (2), 701–728.

Amiti, Mary and Amit K. Khandelwal, "Import Competition and Quality Upgrading," *The Review of Economics and Statistics*, 2013, *95* (2), 476–490.

Antoniades, Alexis, "Heterogeneous Firms, Quality, and Trade," *Journal of International Economics*, 2015, *95* (2), 263–273.

Autor, David, David Dorn, Gordon H Hanson, Gary Pisano, and Pian Shu, "Foreign Competition and Domestic Innovation: Evidence from US Patents," 2017.

Bas, Maria and Vanessa Strauss-Kahn, "Input-Trade Liberalization, Export Prices and Quality Upgrading," *Journal of International Economics*, 2015, *95* (2), 250–262.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum, "Plants and Productivity in International Trade," *American Economic Review*, 2003, *93* (4), 1268–1290.

Berthou, Antoine and Charlotte Emlinger, "The Trade Unit Values Database," Working Papers 2011-10, CEPII 2011.

Bertschek, Irene, "Product and Process Innovation as a Response to Increasing Imports and Foreign Direct Investment," *The Journal of Industrial Economics*, 1995, pp. 341–357.

Blas, Beatriz De and Katheryn N Russ, "Understanding markups in the open economy," *American Economic Journal: Macroeconomics*, 2015, *7* (2), 157–80.

Bloom, Nicholas, Mirko Draca, and John Van Reenen, "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," *The Review of Economic Studies*, 2016, *83* (1), 87–117.

_ , **Paul Romer, Stephen J Terry, and John Van Reenen**, "Trapped Factors and China's Impact on Global Growth," 2018.

Boone, Jan, "Competitive Pressure: the Effects on Iinvestments in Product and Process Innovation," *The RAND Journal of Economics*, 2000, pp. 549–569.

Brandt, Loren, Johannes Van Biesebroeck, Luhang Wang, and Yifan Zhang, "WTO Accession and Performance of Chinese Manufacturing Firms," *American Economic Review*, September 2017, *107* (9), 2784–2820.

Bustos, Paula, "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, February 2011, *101* (1), 304–40.

Eaton, Jonathan and AC Fieler, "The Gravity of Unit Values," Technical Report, Preliminary Working Paper 2017.

_ **and Samuel Kortum**, "Technology in the Global Economy: A Framework for Quantitative Analysis," *Unpublished Manuscript*, 2005.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu, "Competition, markups, and the gains from international trade," *American Economic Review*, 2015, *105* (10), 3183–3221.

Erumban, A, Reitze Gouma, Gaaitzen de Vries, Klaas de Vries, and Marcel Timmer, "WIOD Socio-Economic Accounts (SEA): Sources and Methods," *Groningen*, 2012.

Eslava, Marcela, Ana Cecília Fieler, and Daniel Yi Xu, "Trade, Quality Upgrading, and Input Linkages: Theory and Evidence from Colombia," *American Economic Review*, 2018, *108* (1), 109–46.

Fan, Haichao, Yao Amber Li, and Stephen R. Yeaple, "Trade Liberalization, Quality, and Export Prices," *The Review of Economics and Statistics*, 2015, *97* (5), 1033–1051.

_ , _ , **Sichuang Xu, and Stephen R Yeaple**, "Quality, Variable Markups, and Welfare: A Quantitative General Equilibrium Analysis of Export Prices," 2017.

Feenstra, Robert C and David E Weinstein, "Globalization, markups, and US welfare," *Journal of Political Economy*, 2017, *125* (4), 1040–1074.

Feenstra, Robert C. and John Romalis, "International Prices and Endogenous Quality," *The Quarterly Journal of Economics*, 2014, *129* (2), 477–527.

Feenstra, Robert C, John Romalis, and Peter K Schott, "U.S. Imports, Exports, and Tariff Data, 1989-2001," Working Paper 9387, National Bureau of Economic Research 2002.

Fernandes, Ana M and Caroline Paunov, "Does Trade Stimulate Product Quality Upgrading?," *Canadian Journal of Economics*, 2013, *46* (4), 1232–1264.

Fieler, Ana Cecilia, "Nonhomotheticity and Bilateral Trade: Evidence and a Quantitative Explanation," *Econometrica*, 2011, *79* (4), 1069–1101.

Hallak, Juan Carlos, "Product Quality and the Direction of Trade," *Journal of international Economics*, 2006, *68* (1), 238–265.

— **and Jagadeesh Sivadasan**, "Product and Process Productivity: Implications for Quality Choice and Conditional Exporter Premia," *Journal of International Economics*, 2013, *91* (1), 53–67.

Handley, Kyle and Nuno Lim ao, "Policy Uncertainty, Trade, and Welfare: Theory and Evidence for China and the United States," *American Economic Review*, September 2017, *107* (9), 2731–83.

Head, Keith, Thierry Mayer, and John Ries, "The Erosion of Colonial Trade Linkages after Independence," *Journal of International Economics*, 2010, *81* (1), 1–14.

Holmes, Thomas J. and John J. Stevens, "An Alternative Theory of the Plant Size Distribution, with Geography and Intra- and International Trade," *Journal of Political Economy*, 2014, *122* (2), 369–421.

Hombert, Johan and Adrien Matray, "Can Innovation Help US manufacturing Firms Escape Import Competition from China?," *The Journal of Finance*, 2015.

Hsu, Wen-Tai, Yi Lu, and Guiying Laura Wu, "Competition, Markups, and Gains from Trade: A Quantitative Analysis of China Between 1995 and 2004," 2017.

Krishna, Pravin and Devashish Mitra, "Trade liberalization, market discipline and productivity growth: new evidence from India," *Journal of development Economics*, 1998, *56* (2), 447–462.

Kugler, Maurice and Eric Verhoogen, "Prices, Plant Size, and Product Quality," *The Review of Economic Studies*, 2012, *79* (1), 307–339.

Levinsohn, James, "Testing the imports-as-market-discipline hypothesis," *Journal of International Economics*, 1993, *35* (1-2), 1–22.

Manova, Kalina and Zhiwei Zhang, "Export Prices Across Firms and Destinations*," *The Quarterly Journal of Economics*, 2012, *127* (1), 379–436.

Medina, Pamela, "Import Competition, Quality Upgrading and Exporting: Evidence from the Peruvian Apparel Industry," *University of Toronto mimeo*, 2017.

Melitz, Marc J. and Gianmarco I. P. Ottaviano, "Market Size, Trade, and Productivity," *The Review of Economic Studies*, 2008, *75* (1), 295–316.

Pierce, Justin R. and Peter K. Schott, "The Surprisingly Swift Decline of US Manufacturing Employment," *American Economic Review*, July 2016, *106* (7), 1632–62.

Schott, Peter K., "The Relative Sophistication of Chinese Exports," *Economic Policy*, 2008, *23* (53), 6–49.

Simonovska, Ina and Michael E. Waugh, "The Elasticity of Trade: Estimates and Evidence," *Journal of International Economics*, 2014, *92* (1), 34–50.

_ **and Michael E Waugh**, "Trade Models, Trade Elasticities, and the Gains from Trade," Technical Report, National Bureau of Economic Research 2014.

Smeets, Valrie, Sharon Traiberman, and Frederic Warzynski, "Offshoring and the Shortening of the Quality Ladder: Evidence from Danish Apparel," 2016.

Verhoogen, Eric A., "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector," *The Quarterly Journal of Economics*, 2008, *123* (2), 489–530.

Appendices

A Proofs

A.1 Proof of Proposition 1

First I need to derive the cumulative distribution of U_{1i}. According to (11):

$$F_i(u_1) = \Pr(U_{1i} \leq u_1) = G_i(u_1, u_1) = \exp(\Phi_i u_1^{-\theta_i}) \tag{31}$$

Then Bertrand competition implies the probability of country i being the supplier for a particular good is:

$$\begin{aligned}
\pi_i &= \Pr\{U_{1i} \geq U_{1j}, \quad \forall\, j \neq i\} \\
&= \int_0^\infty \left(\prod_{j \neq i} F_j(u) \right) dF_i(u) \\
&= \int_0^\infty \exp(-\sum_{j \neq i} \Phi_j u^{-\theta_j}) \Phi_i \theta_i u^{-\theta_i - 1} \exp(-\Phi_i u^{-\theta_i}) du \\
&= \Phi_i \theta_i \int_0^\infty u^{-\theta_i - 1} \exp(-\sum_j \Phi_j u^{-\theta_j}) du
\end{aligned}$$

A.2 Proof of Proposition 2

For proving this proposition, I make use of two Lemmas.

Lemma. *Joint distribution of highest (U_1) and second-highest utility (U_2) that can be delivered to the Home market is:*

$$G(u_1, u_2) = exp(-\sum_{i=1}^n \Phi_i u_2^{-\theta_i}) \{1 + \sum_{i=1}^n \Phi_i (u_2^{-\theta_i} - u_1^{-\theta_i})\} \tag{32}$$

Proof.

$$\begin{aligned}
G(u_1, u_2) &= \Pr\{U_1 \leq u_1, U_2 \leq u_2\} \\
&= \prod_{i=1}^n \exp(-\Phi_i u_2^{-\theta_i}) + \sum_{i=1}^n \Phi_i (u_2^{-\theta_i} - u_1^{-\theta_i}) \exp(-\Phi_i u_2^{-\theta_i}) \prod_{j \neq i} \exp(-\Phi_j u_2^{-\theta_j}) \\
&= \exp(-\sum_{i=1}^n \Phi_i u_2^{-\theta_i}) \{1 + \sum_{i=1}^n \Phi_i (u_2^{-\theta_i} - u_1^{-\theta_i})\}
\end{aligned} \tag{33}$$

□

where the second line breaks the probability into two parts: probability that the highest utility from all source countries is less than u_2 (first term) plus the probability that the highest utility sourced from i is greater than u_2 but less than u_1 and second-highest utility sourced from i and the highest utility sourced from rest of the world is less u_2 and then summing this probability across all countries (second term).

Lemma. *Joint distribution of highest (U_1) and second-highest utility (U_2) in the Home market conditional on country i being the source is:*

$$G(u_1, u_2|i \textit{ source}) = \frac{\Phi_i \theta_i}{\pi_i} \int_0^{u_2} x^{-\theta_i - 1} \exp(-\sum_{j=1}^{n} \Phi_j x^{-\theta_j}) dx \; + \frac{\Phi_i}{\pi_i}(u_2^{-\theta_i} - u_1^{-\theta_i}) \exp(-\sum_{j=1}^{n} \Phi_j u_2^{-\theta_j}) \tag{34}$$

Proof.

$$\begin{aligned} G(u_1, u_2|i \text{ source}) =& \Pr\{U_1 \leq u_1, U_2 \leq u_2|i \text{ source}\} \\ =& \frac{\Pr\{U_1 \leq u_1, U_2 \leq u_2, i \text{ source}\}}{\Pr\{i \text{ source}\}} \\ =& \frac{\int_0^{u_2} \exp(-\sum_{j \neq i} \Phi_j x^{-\theta_j}) \Phi_i \theta_i x^{-\theta_i - 1} \exp(-\Phi_i x^{-\theta_i}) dx}{\pi_i} \\ &+ \frac{\Phi_i (u_2^{-\theta_i} - u_1^{-\theta_i}) \exp(-\Phi_i u_2^{-\theta_i}) \prod_{j \neq i} \exp(-\Phi_j u_2^{-\theta_j})}{\pi_i} \\ =& \frac{\Phi_i \theta_i}{\pi_i} \int_0^{u_2} x^{-\theta_i - 1} \exp(-\sum_{j=1}^{n} \Phi_j x^{-\theta_j}) dx \; + \frac{\Phi_i}{\pi_i}(u_2^{-\theta_i} - u_1^{-\theta_i}) \exp(-\sum_{j=1}^{n} \Phi_j u_2^{-\theta_j}) \end{aligned} \tag{35}$$

□

Now in the case of cobb-douglas utility, plugging $\sigma = 1$ into equations 32 and 34 yields simple forms:

$$G^{c-d}(u_1, u_2) = G^{c-d}(u_1, u_2|i \text{ source}) = \exp(-\Phi u_2^{-\theta})\{1 + \Phi(u_2^{-\theta} - u_1^{-\theta})\} \tag{36}$$

where $\Phi = \sum_{i=1}^{n} \Phi_i$ and superscript $c - d$ refers to the cobb-douglas utility.

Total export value of country i to Home market is equal to $V_i = M_i E(v_i|i \text{ source})$ where M_i is the measure products exported by i and v_i is the export value of a typical product exported by i. Normalizing measure of all products consumed in

the Home market to one, then $M_i = \pi_i$. Given that $v_i = EP^{\sigma-1}U_2^{\sigma-1}$, then country i's trade share s_i would be:

$$\begin{aligned} s_i &= \frac{\pi_i E(v_i|i \text{ source})}{\sum_j \pi_j E(v_i|j \text{ source})} \\ &= \frac{\pi_i E(U_2^{\sigma-1}|i \text{ source})}{\sum_j \pi_j E(U_2^{\sigma-1}|j \text{ source})} \\ &= \pi_i = \frac{\Phi_i}{\Phi} \end{aligned}$$

The third equality comes from the fact that since $G^{c-d}(u_1, u_2|i \text{ source})$ is identical for all $i = 1, ..., n$, hence: $E(U_2^{\sigma-1}|i \text{ source}) = E(U_2^{\sigma-1}|j \text{ source}) \ \forall \ i, j$. Fourth equality follows when substituting $\sigma = 1$ in equation 14. This proves Proposition 2.

A.3 Proof of Proposition 3

Let's first derive the distribution of U_2/U_1 conditional on $U_2 = u$:

$$\begin{aligned} \Pr\left(\frac{U_2}{U_1} \leq x \ |U_2 = u\right) &= \frac{\int_{\frac{u}{x}}^{\infty} g^{c-d}(u_1, u)du_1}{\int_u^{\infty} g^{c-d}(u_1, u)du_1} \\ &= x^{\theta} \end{aligned}$$

Since the distribution of U_2/U_1 conditional on $U_2 = u$ doesn't depend on the value of u, then it would be equal to the unconditional distribution:

$$\Pr\left(\frac{U_2}{U_1} \leq x\right) = \Pr\left(\frac{U_2}{U_1} \leq x \ |U_2 = u\right) = x^{\theta}$$

A.4 Proof of Proposition 5

Part (i).
we need to show $h_2(\zeta|\varphi) \succsim h_1(\zeta|\varphi)$. So first let's derive $h_1(\zeta|\varphi)$:

$$h_1(\zeta|\varphi) = \Pr(z_i \leq \zeta|\varphi) = \Pr\left(\bar{z}_i \left(\frac{U_2}{U_1}\right)^{\frac{1}{\beta_i+\alpha-\gamma}} \leq \zeta|\varphi\right)$$

I have assumed that country i is the nationality of firm φ but the identity of source country doesn't matter in this part. Since we have conditioned on φ and according

to equation 10, U_1 is completely determined by φ ($U_1 = U_i(\varphi) = A_i\varphi^{\frac{1}{1-(\sigma-1)\lambda_i}}$) then we can write:

$$\begin{aligned}
h_1(\zeta|\varphi) &= \Pr\left(U_2 \leq \left(\frac{\zeta}{\bar{z}_i}\right)^{\beta_i+\alpha-\gamma} U_1 | U_1 = U_i(\varphi)\right) \\
&= \frac{\Pr\left(\left(U_2 \leq \left(\frac{\zeta}{\bar{z}_i}\right)^{\beta_i+\alpha-\gamma} U_i(\varphi)\right) \cap (i \text{ source})\right)}{\Pr\left((U_1 = U_i(\varphi)) \cap (i \text{ source})\right)} \\
&= \frac{\Phi_i \left(\left(\frac{\zeta}{\bar{z}_i}\right)^{\beta_i+\alpha-\gamma} U_i(\varphi)\right)^{-\theta} \exp\left(-\Phi_1 \left(\frac{\zeta}{\bar{z}_i}\right)^{-\theta(\beta_i+\alpha-\gamma)} U_i(\varphi)^{-\theta}\right)}{\Phi_i \theta U_i(\varphi)^{-\theta-1} \exp\left(-\Phi_1 U_i(\varphi)^{-\theta}\right)} \\
&= \frac{\left(\frac{\zeta}{\bar{z}_i}\right)^{-\theta(\beta_i+\alpha-\gamma)} U_i(\varphi)}{\theta} \exp\left(-\Phi_1 U_i(\varphi)^{-\theta}\left(\left(\frac{\zeta}{\bar{z}_i}\right)^{-\theta(\beta_i+\alpha-\gamma)} - 1\right)\right)
\end{aligned}$$

where Φ_1 captures competetiveness of Home market before trade policy. It is clear that reducing trade barrier with a country, increase the competetiveness of Home market by increasing Φ_1. So the expression for $h_2(\zeta|\varphi)$ can be obtained by replacing Φ_1 by Φ_2 where $\Phi_2 > \Phi_1$. Then we can conclude that $h_2(\zeta|\varphi) < h_1(\zeta|\varphi)$ which proves the claim.

Part (ii).

According to Proposition 2, trade share of country i is equal to

$$\pi_i = \frac{\Phi_i}{\Phi}$$

Reducing trade barrier d_i, changes trade shares of exporting countries according to:

$$\frac{\partial \pi_j}{\partial d_i} = \begin{cases} \frac{\theta}{d_i}\pi_i\pi_j & \text{if} \quad j \neq i \\ \frac{-\theta}{d_i}\pi_i(1-\pi_i) & \text{if} \quad j = i \end{cases}$$

Now taking derivative of quality distribution $H(\zeta)$ with respect to d_i gives:

$$\begin{aligned}
\frac{\partial H(\zeta)}{\partial d_i} =& \sum_{i=1}^{n} \frac{\partial \pi_j}{\partial d_i} \left(\frac{\zeta}{\bar{z}_i}\right)^{\theta(\beta_i+\alpha-\gamma)} \\
=& \frac{\theta\pi_i}{d_i} \sum_{j\neq i} \pi_j \bar{z}_j^{-\theta(\beta_j+\alpha-\gamma)} \zeta^{\theta(\beta_j+\alpha-\gamma)} - \frac{\theta\pi_i}{d_i}(1-\pi_i)\bar{z}_i^{-\theta(\beta_i+\alpha-\gamma)}\zeta^{\theta(\beta_i+\alpha-\gamma)} \\
=& \frac{\theta\pi_i}{d_i} \sum_{j\neq i} \pi_j \bar{z}_j^{-\theta(\beta_j+\alpha-\gamma)} \zeta^{\theta(\beta_j+\alpha-\gamma)} - \frac{\theta\pi_i}{d_i} \sum_{j\neq i} \pi_j \bar{z}_i^{-\theta(\beta_i+\alpha-\gamma)}\zeta^{\theta(\beta_i+\alpha-\gamma)} \\
=& \zeta^{\theta(\alpha-\gamma)} \frac{\theta\pi_i}{d_i} \sum_{j\neq i} \pi_j \left(F_j\zeta^{\theta\beta_j} - F_i\zeta^{\theta\beta_i}\right) \qquad (37)
\end{aligned}$$

where $F_j = \bar{z}_j^{-\theta(\beta_j+\alpha-\gamma)}$.

Assumption of part II says that country i's quality is stochastically inferior to average quality in the Home market. Therefore,

$$
\begin{aligned}
H_i(\zeta) \precsim H(\zeta) \Rightarrow \left(\frac{\zeta}{\bar{z}_i}\right)^{\theta(\beta_i+\alpha-\gamma)} &\geq \sum_{j=1}^{n} \pi_j \left(\frac{\zeta}{\bar{z}_j}\right)^{\theta(\beta_j+\alpha-\gamma)} \\
\Rightarrow F_i \zeta^{\theta\beta_i} &\geq \sum_{j=1}^{n} \pi_j F_j \zeta^{\theta\beta_j} \\
\Rightarrow \sum_{j=1}^{n} \pi_j F_i \zeta^{\theta\beta_i} &\geq \sum_{j=1}^{n} \pi_j F_j \zeta^{\theta\beta_j} \\
\Rightarrow \sum_{j=1}^{n} \pi_j \left(F_j \zeta^{\theta\beta_j} - F_i \zeta^{\theta\beta_i}\right) &\leq 0 \\
\Rightarrow \sum_{j\neq i} \pi_j \left(F_j \zeta^{\theta\beta_j} - F_i \zeta^{\theta\beta_i}\right) &\leq 0 \qquad (38)
\end{aligned}
$$

Combining 37 and 38 yields:

$$\frac{\partial H(\zeta)}{\partial d_i} \leq 0$$

This means that reducing trade barrier d_i, stochastically downgrade the quality distribution.

Table 7: List of Countries

Country	ISO3 Code	Labor Force (thousands)	Wage (US$)	GDP (Million US$)
Australia	AUS	9012	25881	376634
Austria	AUT	3931	30821	178172
Belgium	BEL	4109	34997	214342
Bulgaria	BGR	3239	1560	10292
Brazil	BRA	78972	3577	567321
Canada	CAN	15048	25776	675314
China	CHN	720850	844	1199693
Cyprus	CYP	315	29548	15171
Czech Republic	CZE	4940	6150	53082
Germany	DEU	39144	30970	1772483
Denmark	DNK	2712	34814	142350
Spain	ESP	16412	21351	544827
Estonia	EST	573	5179	5257
Finland	FIN	2293	30381	109876
France	FRA	24332	31697	1232529
United Kingdom	GBR	29617	30829	1323724
Greece	GRC	4255	14619	114952
Hungary	HUN	4250	6186	42040
Indonesia	IDN	93321	880	164235
India	IND	416883	574	453137
Ireland	IRL	1697	28785	89437
Italy	ITA	22930	28205	1016047
Japan	JPN	65253	41780	4724855
South Korea	KOR	21136	17193	486734
Lithuania	LTU	1399	3741	10289
Luxembourg	LUX	264	39266	18738
Latvia	LVA	941	3890	7186
Mexico	MEX	39226	5352	585439
Malta	MLT	146	12949	3361
Netherlands	NLD	8115	29213	356573
Poland	POL	15018	7893	151266
Portugal	PRT	5030	13548	101738
Romania	ROM	10771	2086	34052
Russia	RUS	73726	1823	236179
Slovakia	SVK	2025	5248	26546
Slovenia	SVN	905	12513	15366
Sweden	SWE	4301	34965	225382
Turkey	TUR	21580	4677	239733
United States	USA	147717	41164	9950002

B List of Countries

C Detailed Estimation Results

Table 8: Estimated Values for Technology and Quality Parameters

Country	$\log(T)$	β	Country	$\log(T)$	β
Australia	0	4.412	Ireland	-0.637	4.365
Austria	0.129	4.442	Italy	1.009	4.586
Belgium	0.821	4.594	Japan	2.946	4.107
Bulgaria	-12.668	6.369	South Korea	-1.097	4.930
Brazil	-7.298	5.463	Lithuania	-9.264	5.691
Canada	0.140	4.517	Luxembourg	-0.593	4.562
China	-12.032	6.876	Latvia	-9.317	5.693
Cyprus	-0.814	4.668	Mexico	-5.801	5.223
Czech Republic	-6.404	5.515	Malta	-5.241	4.786
Germany	1.640	4.567	Netherlands	0.644	4.650
Denmark	0.600	4.343	Poland	-4.714	5.469
Spain	-0.311	4.792	Portugal	-3.072	4.896
Estonia	-8.433	5.498	Romania	-10.882	5.934
Finland	0.049	4.521	Russia	-10.265	5.963
France	1.420	4.453	Slovakia	-7.302	5.736
United Kingdom	1.296	4.387	Slovenia	-4.411	5.154
Greece	-2.619	4.938	Sweden	0.929	4.378
Hungary	-6.613	5.306	Turkey	-6.429	5.767
Indonesia	-13.265	6.353	United States	3.703	4.500
India	-14.472	6.434			