Escaping Import Competition in China

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Abstract

We propose and provide evidence for a new source of gain from trade: Firms differentiate their products to escape import competition. Facing a nested CES demand, heterogeneous firms choose between producing a variety in a nest with competitors or incurring a higher cost to be a monopolist in a new nest. The gain from differentiation is an inverted U-shaped function of firm productivity, and it is larger for the social planner values than for private firms. We use establishment data from China spanning its WTO accession in 2001. In the data, tariff cuts are associated with increases in revenue productivity, introduction of new goods, and switches to skill-intensive sectors within firms. These patterns are in line with the prediction that import competition increases product innovation. Variable markups explain the effect of tariff cuts on the revenue productivity of firms with heterogeneous sizes.

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1 Introduction

Policy makers and trade economists generally agree that trade reforms improve the performance of domestic competitors, even though the theoretical and empirical underpinnings for this view remain elusive. Evidence on the effect of tariff or quota reductions on firm productivity is mixed, and if forced to explain a mechanism, a number of economists might vaguely resort to "x-inefficiency" or "dynamic gains from trade."[1] This paper aims to, at least in part, narrow the gap between policy makers' perceptions and the academic literature.

In response to lower import tariffs, firms often differentiate their products by seeking market niches that are insulated from foreign competition. They cater to domestic tastes, offer greater customization, and complement products with non-tradable services. Anecdotes abound from the Chinese accession to the WTO in 2001, the object of our empirical analysis. Shortly after 2001, the automobile company Chery introduced several new, small car models with many optional features, and it made replacement parts readily available. These changes insulate Chery from import competition because it is difficult for firms producing cars abroad to offer customized accoutrements and a wide range of replacement parts. Similarly, the cell phone company Xiaomi prevented the expansion of Apple in China by offering Chinese language options and a superior integration of its software with local apps.[2]

We capture this sort of reaction to foreign competition in a model with heterogeneous firms and a demand system with nested constant elasticity of substitution (CES). Firms compete à la Bertrand and have endogenous markups. In addition, each firm chooses between (1) producing a variety in a less-differentiated nest with a high elasticity of substitution between varieties, and (2) incurring a higher (fixed or variable) cost to produce in a new nest where it is a monopolist. This choice of product differentiation is our only departure from the simplest version of Atkeson and Burstein (2008).

In the model, the net profit from product differentiation is a non-monotonic function of firm productivity. If the firm is very unproductive, its profit is small irrespective of whether it produces a differentiated variety or not. If the firm is much more productive

[1]See Holmes and Schmitz (2010) for theories and case studies based on x-inefficiencies. Tybout (2003) surveys of studies on the trade liberalizations in developing countries in the 1980s and 1990s. Mixed evidence appears in more recent papers, e.g., Amiti and Konings (2007), Eslava et al. (2013), DeLoecker et al. (2016) and Steinwender (2015). Our empirical findings do not preclude the presence of x-inefficiencies, but our mechanisms has specific predictions that are bore out by the data.

[2]See Farhoomand and Schuetz (2007), Boyd et al. (2008), Teagarden and Fifi (2015), Feng and Wei (2015). In interviews with Foreign Affairs (Rose (2015)), American entrepreneurs emphasize their search for market niches where they can enjoy monopoly power.

than its competitors, then it will hold near monopoly power and charge a high markup even in the less-differentiated nest. The benefit from further differentiation is small.

When competition tightens in the less-differentiated nest, the profit from escaping competition to a new nest increases for all firms. To understand the effects of foreign competition, we assume that at least some foreign firms are in the less-differentiated nest. The interpretation is that differentiated goods are less tradable because they cater to domestic tastes and are complemented with non-tradable services. Then, a reduction in foreign costs increases product differentiation among import-competing firms, in line with the anecdotes above. We extend the model to general equilibrium and show that the private profit from product differentiation is smaller than the social benefit. A greater product differentiation, spurred by import competition, is a gain from trade not previously identified in the literature. A back-of-the-envelope calculation in Section 4 shows that such gain may be sizable.

We seek evidence for the proposed mechanisms in panel data of Chinese firms from 1998 to 2007, spanning the year of China's accession to the WTO in 2001. Average tariffs on manufacturing in China fell from 43 percent in 1994 to 9.4 percent in 2004. Imports as a share of GDP doubled from 14 percent in 1998 to a peak of 28 percent in 2006. In the data, tariff cuts are associated with increases in revenue productivity, the introduction of new goods, and switches to more skill-intensive sectors.[3] These facts, we argue, are at odds with existing models of international trade, where import competition decreases sales and markups. It leads firms to divest in cost-reducing technologies, drop their least productive varieties, and switch to unskill-intensive sectors in an unskill-abundant country. (See Section 2.4.)

Greater product differentiation may rationalize these empirical findings. Firms that differentiate introduce new goods, and often upgrade their quality and switch to skill-intensive activities. For example, to offer greater variety and customization of car features, the automobile company Chery invested in research and development, modern machinery, and integrated computer systems. Some common sector switches in the data include from cotton and chemical fibers to textile and garments manufacturing, and from steel rolling processing to metal structures (Section 2.3). They suggest upgrading to higher value-added sectors with a greater the scope for differentiation.

The advantage of a model with variable markups is that it speaks directly to revenue productivity, a measure of the ratio of revenue to cost. In the model, this ratio increases

[3]Tariff cuts increase the probability of switching sectors and of switching to a more skill intensive sector conditional on switching. To establish causality, we follow the literature in using initial tariffs as instruments for tariff changes. See Goldberg et al. (2009), Amiti and Konings (2007), Attanasio et al. (2004). We cannot observe changes in skill intensity because we only observe skill intensity in one year.

with the markup, which in turn increases with product differentiation and decreases with tighter competition. Tariff cuts lead import-competing firms to differentiate their products and to decrease their markups for a given level of differentiation. These opposing effects may explain the mixed findings of the effect of tariff cuts on firm productivity in the literature. For the Chinese experience, these effects are positive, but small.

We find two instances where the productivity responses to tariff cuts in the data differ from the responses of the other non-pecuniary firm outcomes—the introduction of new goods and switches to more skill-intensive sectors—which we use as proxies for product differentiation. First, the productivity response to tariff cuts decreases systematically with quartile of sales, while the response of non-pecuniary firm outcomes is the same across quartiles of sales. In line with this finding, we prove that import competition increases the markup of small firms relative to large firms if firms of all sizes have similar propensities to differentiate their products. Second, the productivity response to tariff cuts is at least seven times larger for import-competing firms' input suppliers than the response of import-competing firms themselves. The movement in non-pecuniary firm outcomes is generally smaller for input suppliers than for import-competing firms. We extend the model to include input suppliers and show that these firms increase both differentiation and markups in response to import-competition downstream, again in line with the data. In sum, predicted changes in markups in the model coincide with observed changes in revenue productivity in the data, even when these predictions and empirical regularities are different from those of non-pecuniary firm outcomes. This result suggests caution in interpreting changes in measured productivity during large trade liberalizations episodes.[4]

Holmes and Stevens (2014) also observe that firms offering customized products are more insulated from foreign competition. We extend their model to account for endogenous product differentiation and variable markups. Consistent with our findings, Brandt and Thun (2010) and Brandt and Thun (2016) describe the increased market segmentation in China during the period of our analysis.[5]

The result that the profit from innovation is an inverted U-shape is reminiscent of Aghion et al. (2005) and Aghion et al. (2015). In these models, innovation reduces the cost of producing a homogeneous good, and only the most productive firm produces. Our

[4]Methods to estimate TFP and to separate it from markups generally assume technology changes are Hicks neutral and goods are homogeneous. These assumptions that are violated by the model and arguably the data as trade changes firms' residual demand functions, and innovation changes output and production processes. See Section 3.1 for discussion and references.

[5]Fort et al. (2018) associate import penetration in the United States to shifts of manufacturing firms to the service sector. This finding is also in line with our thesis that firms complement their output with non-tradable services to escape foreign competition.

use of CES preferences with differentiated varieties brings their results closer to recent quantitative trade models. Starting with Feenstra and Hanson (1997), recent papers propose theories where international trade leads firms to upgrade their quality or technologies in unskill-abundant developing countries.[6] Upgrades in these theories occur through export expansion, imported inputs or capital, and we propose import competition as an additional mechanism.

To our knowledge, the effects of tariff cuts on the input suppliers of import-competing firms have not been previously documented. These results are part of a growing literature that highlights the role of domestic input linkages in propagating and augmenting the direct effects of international trade on firms, such as Kee and Tang (2016), Fieler et al. (2018), Linarello (2018), and Tintelnot et al. (2018).[7] Our results on the welfare effects of product differentiation complement the results on optimal variety in Dixit and Stiglitz (1977) and Dhingra and Morrow (2018).

The description of the data, empirical specification, and results are in Section 2. Section 3 presents a simple, partial equilibrium model that rationalizes the empirical findings. Section 4 extends the model to general equilibrium to analyze welfare. Section 5 extends the model to include intermediate inputs. Appendix A tests other predictions of the model and checks the robustness of the empirical results. Section 6 summarizes these data exercises. Section 7 concludes.

2 Data and Evidence

We analyze the effect of tariff changes on firm outcomes that are often associated with innovation or quality upgrading in the literature: productivity, introduction of new goods, and skill intensity. We describe the data sources in Section 2.1, the empirical specification in Section 2.2, and the results in Section 2.3. Given the relevance of Chinese accession to the WTO, these results are themselves of interest. They motivate the model because they are hard to reconcile with existing models, as we argue in Section 2.4.

[6] This literature is typically concerned with explaining the increased demand for skilled workers following trade liberalizations in developed countries. See Yeaple (2005), Burstein and Vogel (2016), Burstein et al. (2016), Helpman et al. (2017), Fieler et al. (2018), and Lee (2018). Goldberg and Pavcnik (2004) and Goldberg and Pavcnik (2007) survey empirical works.

[7] Our empirical approach is closely related Javorcik (2004) and Blalock and Gertler (2008) used to study spillovers in foreign direct investment. The direct effects of imported inputs are in Amiti and Konings (2007), Goldberg et al. (2010), Halpern et al. (2015), Bøler et al. (2015), and Brandt et al. (2017) for China.

2.1 Data Sources

The data are an annual survey of industrial firms collected by the Chinese National Bureau of Statistics. The survey is at the establishment level and comprises *all* state-owned enterprises (SOEs), regardless of size, and *all* non-state-owned firms (non-SOEs) with annual sales of more than 5 million yuan. We use a ten-year unbalanced panel from 1998 to 2007. These data are extensively used in a number of papers, and for more details, we refer the reader to Du et al. (2012), Aghion et al. (2015), and Brandt et al. (2017).

The original dataset has 2,226,104 firm-year observations and contains identifiers that can be used to track firms over time. We keep only firms in manufacturing, the more tradable sector. We delete observations with missing values, or with zero or negative values for output, number of employees, capital, and material inputs. Output price indices by sector are reported annually in the official publication. We dropped three sectors from the sample due to missing data on price indices.

The data contain information on output, fixed assets, total workforce, total wages, intermediate input costs, foreign investment, Hong Kong-Taiwan-Macau investment, sales revenue, and export sales. We classify firms as domestic or foreign-owned. Domestic firms are those with zero foreign capital in their total assets. About 77.5 percent of firms are classified as domestic and 22.5 percent as foreign-owned. Most of our analysis restricts the sample to domestic firms with zero or a minority state ownership, but we confirm that our results are robust to including multinationals and state owned enterprises. The final sample has 1,037,738 observations.

Our time series of tariffs is the World Integrated Trading Solution (WITS), maintained by the World Bank. To measure tariffs on sectors upstream and downstream from each firm's own sector, we use Chinese Input-Output table (2002). The sectoral classification in the input-output table is more aggregate than the 4-digit classification in the firm survey. So, we create a concordance between the tariff data, the input-output table, and the survey data at the most disaggregated level possible. The aggregation uses output in 2003 as weights. We end up with 71 sectors that comprise a wide range of economic activities, such as ship-building, electronic computers, tobacco products, motor vehicles, and parts and accessories for motor vehicles.

2.2 Empirical Specification

Our basic regression specification is:

$$
\begin{aligned}
y_{it} =& \beta_1 \ln \text{Output\_Tariff}_{j(i,t)t} + \beta_2 \ln \text{Upstream\_Tariff}_{j(i,t)t} + \beta_3 \ln \text{Downstream\_Tariff}_{j(i,t)t} \\
&+ \gamma_1 X_{j(i,t)t} + \gamma_2 X_{i,t} + \alpha_i + \alpha_t + \varepsilon \qquad (1)
\end{aligned}
$$

where the subscripts refer to firm i, year t, and sector $j(i,t)$ of firm i at time t. Variable y_{it} is an outcome of interest, α_i are firm fixed effects, and α_t are time fixed effects. Control variables are at the sector-time level X_{jt} and at the firm-time level X_{it}. These controls and tariff measures are detailed below. We cluster standard errors by firm and by the firm's initial sector.

Tariffs For each firm and year, we construct three measures of the tariffs that China imposes on its imports. Consider a firm in sector j. First, *output tariffs* are tariffs on the firm's own sector j. Second, *upstream tariffs* are tariffs on the sectors that provide inputs to sector j. The literature refers to them as input tariffs, and we change the nomenclature to make it symmetric to the novel concept of downstream tariffs. Third, *downstream tariffs* are tariffs on the sectors to which firms in sector j provide inputs.

Consider the example of a firm that produces car engines. It may be impacted by Chinese entry into the WTO if the tariffs on the pistons that go into engines decrease (upstream tariff), if the tariffs on car engines decrease (output tariff) increasing import competition, or if tariffs on cars decrease (downstream tariff) and change the type of car Chinese producers make.

Output tariffs are measured at the four-digit level, while upstream and downstream tariffs are measured at the 71-sectoral classification, as described above. Our measure of upstream tariffs follows Amiti and Konings (2007) and is used by Brandt et al. (2017) for China.[8] Upstream tariff is a weighted average of output tariffs:

$$\text{upstream\_tariff}_{jt} = \sum_{m \neq j} \delta_{jm} \text{ output\_tariff}_{mt}$$

where the weight δ_{jm} is the share of sector m in all of sector j's inputs. Downstream tariff

[8] We take our upstream and output tariffs directly from Brandt et al. (2017), who study China in the same period with the same data sources.

is calculated analogously as:

$$\text{downstream\_tariff}_{jt} = \sum_{k \neq j} \alpha_{jk} \text{ output\_tariff}_{kt}$$

where α_{jk} is the share of sector j's production supplied to downstream sector k. The values of α_{jk} and δ_{jm} are both taken from the 2002 Chinese Input-Output table. These weights α_{jk} and δ_{jm} do not add up to one because inputs include labor and capital, and part of output goes to final consumption. Downstream tariffs will be highest in those sectors j where the downstream users in sector k face high tariffs and demand a large share of sector j's output.

Instruments for tariffs The high level of aggregation at which upstream and downstream tariffs are measured, 71 sectors, partly mitigates the concern that individual firms endogenously influence the level of tariffs through lobbying. Still, we use an instrumental variable to further address the potential endogeneity of tariffs. Similar to other trade liberalizations, China reduced both the level and the heterogeneity in tariffs. Between 1998 to 2007, tariff reductions were larger in sectors with high tariffs at the beginning of the sample period, in 1998.

Following the literature, we use initial tariffs as instruments.[9] Output tariffs, upstream tariffs, and downstream tariffs are instrumented using the initial value for these tariffs at the firm level interacted with a dummy variable equal to one after China entered the WTO. We cannot use the initial tariffs alone as an instrument because our regressions have firm fixed effects.

Additional control variables Control variables capture exposure to foreign investment and state ownership at the sector-time level, and policy variables at the firm-time level. We control for the share of state ownership in the sector of the firm at time t. We define three sector-level FDI variables following Javorcik (2004). $\text{Horizontal\_FDI}_{jt}$ captures foreign presence in sector j at time t, and it is a weighted average of foreign equity participation in each firm in sector j, where the weights are the firm's share in sectoral output. $\text{Downstream\_FDI}_{jt}$ is a measure of foreign participation in the sectors that are supplied by sector j, i.e., in sectors downstream from j. Upstream_FDI_{jt} is a measure of foreign participation in sectors upstream from j. We refer the reader to Javor-

[9]For example, Goldberg et al. (2009) use this instrument for India, Amiti and Konings (2007) use it for Indonesia, and Attanasio et al. (2004) use it for Colombia. Brandt et al. (2017) follow a similar approach for instrumenting Chinese tariffs. They instrument for tariffs using rates from the accession agreement, which were mostly fixed by 1999.

cik (2004) for details on the construction of these FDI variables. We control for industrial policy through zero-one dummy variables indicating whether the firm received subsidies (index_subsidies), whether the firm received a tax holiday (index_tax), and whether the firm paid below median interest rates on loans (index_interest). Compared to other studies, our control variables are very detailed, but level of aggregation is high—Amiti and Konings (2007), for instance, use 4-digit measures of protection for Indonesia, while we can only use 3-digit measures for tariffs and FDI.

Revenue Total Factor Productivity (TFP) Our main measure of revenue TFP uses the standard two-stage procedure in Olley and Pakes (1996) to estimate the following gross-output production function separately for each 2-digit sector:

$$\ln X_{it} = \alpha_{0j(i,t)} + \alpha_{Lj(i,t)} \ln L_{it} + \alpha_{Mj(i,t)} \ln M_{it} + \alpha_{Kj(i,t)} \ln K_{it} + \mu_{it} \tag{2}$$

where X is deflated output, L is number of employees, K is capital, M is material inputs, and α_{0j}, α_{Lj}, α_{Kj} and α_{Mj} are sector-specific parameters to be estimated.[10] Our estimated $\ln TFP_{it}$ is the predicted value of $\ln X_{it} - \hat{\alpha}_{Lj(i,t)} \ln L_{it} - \hat{\alpha}_{Mj(i,t)} \ln M_{it} - \hat{\alpha}_{Kj(i,t)} \ln K_{it}$. The results below are robust to measuring TFP à la Ackerberg et al. (2015) in Appendix A.1.

2.3 Empirical Results

Revenue TFP Table 1 shows the results from regression (1) when the dependent variable is $\ln TFP_{it}$. The regression includes sector fixed effects due to the concern that TFP may not be comparable across sectors.[11] TFP in (2) is measured either following Olley-Pakes (OP) or OLS with fixed effects (FE), as indicated in each column.

The coefficients on output tariffs, downstream tariffs, and upstream tariffs in the first three rows are negative and statistically significant in all specifications: Reductions in these tariff measures are associated with increases in TFP. The OLS estimates are in Columns (1) and (2), and we instrument for tariffs (IV) in Columns (3) and (4). The coefficient on the WTO dummy interacted with initial tariff levels in the first stage is

[10] All output and input variables are deflated. Output value (quantities*prices) is deflated by the 29 individual sector ex-factory price indices of industrial products. To deflate material inputs, these 29 sector price indices are assigned with as much consistency as possible to the output data for the 71 sector aggregates. Capital is defined as the net value of fixed assets, which is deflated by a uniform fixed assets investment index, and labor is a physical measure of the total number of employees. Intermediate inputs used for production are deflated by the intermediate-input price index.

[11] In Appendix A.1, the results hold also without these sector fixed effects. For the other outcome variables, we do not include sector fixed effects to capture product innovation that may be accompanied by firms switching between 4-digit sectors. Similar results appear in Brandt et al. (2017) and Yu (2014).

Table 1: Basic Regressions of Productivity on Tariffs

Dependent variable: TFP measured à la Olley-Pakes (OP) or OLS with fixed effects (FE)

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
measure of TFP ⟶	OP	FE	OP	FE	OP	FE
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0304***	-0.0322***	-0.0505***	-0.0477***	-0.0617***	-0.0580***
	(0.0027)	(0.0028)	(0.0169)	(0.0184)	(0.0158)	(0.0170)
downstream_tariff	-0.0179**	-0.0194**	-0.178***	-0.173***	-0.421***	-0.444***
	(0.0070)	(0.0079)	(0.0627)	(0.0641)	(0.0650)	(0.0672)
upsrteam_tariff	-0.132***	-0.141***	-0.369***	-0.483***	-0.227**	-0.323***
	(0.0118)	(0.0130)	(0.0975)	(0.1020)	(0.0907)	(0.0938)
index_subsidy	0.0106***	0.0128***	0.0100***	0.0120***	0.00745***	0.00875***
	(0.0012)	(0.0012)	(0.0012)	(0.0012)	(0.0015)	(0.0015)
index_tax	0.0216***	0.0220***	0.0213***	0.0217***	0.0210***	0.0215***
	(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0010)	(0.0010)
index_interest	-0.0121***	-0.0133***	-0.0119***	-0.0132***	-0.0133***	-0.0144***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)	(0.0010)	(0.0010)
exportshare_sector	0.121***	0.166***	0.398***	0.488***	0.479***	0.578***
	(0.0352)	(0.0357)	(0.0513)	(0.0539)	(0.0582)	(0.0615)
State_share	0.000537	0.0012	0.000136	0.000733	0.00176	0.00279
	(0.0037)	(0.0037)	(0.0037)	(0.0037)	(0.0042)	(0.0043)
Horizontal FDI	0.145***	0.204***	0.135***	0.187***	0.224***	0.286***
	(0.0394)	(0.0420)	(0.0412)	(0.0439)	(0.0487)	(0.0513)
Downstream FDI	1.184***	1.108***	1.718***	1.652***	2.281***	2.262***
	(0.1940)	(0.2060)	(0.2760)	(0.2890)	(0.2960)	(0.3120)
Upstream FDI	0.0926	0.1	0.156**	0.185**	0.042	0.0726
	(0.0724)	(0.0736)	(0.0752)	(0.0764)	(0.0786)	(0.0795)
Observations	1,037,738	1,037,738	1,037,738	1,037,738	826,072	826,072
F statistic, log(output tariff) = log(downstream tariff)	3.1	2.6	4.3	4.0	31.8	34.3
First Stage F, output tariff	-	-	277.6	277.6	349.8	349.8
First Stage F, downstream tariff	-	-	630.1	630.1	524.1	524.1
First Stage F, upstream tariff	-	-	142.8	142.8	161.8	161.8

Standard errors are clustered by firm and initial sector. Tariffs and TFP are in logs. All specifications include fixed effects for the firm, time, and two-digit sector. All specifications also include a dummy variable equal to 1 if the firm changes a four digit sector. IV estimates use initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

highly significant and negative (F-statistics reported), indicating that China's entry into the WTO led to significant tariff declines, especially in manufacturing sectors with high initial tariffs. For the IV estimates, the coefficient on output tariffs in the OP and FE productivity measures are respectively -0.0505 and -0.0477. A ten percent reduction in tariffs raises TFP by about 0.5 percent. Columns (5) and (6) repeat the estimation only with non-exporting firms. The coefficients above increase in absolute value to -0.0617 and -0.0580, respectively, suggesting that import competition has a positive effect on TFP beyond firms' participation in global value chains and export markets.

New goods We use two measures of the introduction of new goods as the dependent variable in regression (1). First is the share of new products in total sales, as reported in the survey. Second is a dummy variable equal to one if the firm introduces a new product in a particular year and zero otherwise.

The results are in Table 2. In all specifications, the coefficient on output tariffs is negative indicating that import-competing firms introduce new goods in response to tariff cuts. For example in the IV columns (2) and (4), the coefficients indicate that a one standard deviation reduction in log output tariffs, around 0.5, is associated with an increase of 0.8 percentage points in the share of new products in total sales (0.5 multiplied by -0.0157), and with an increase of 2 percentage points in the probability of introducing a new product (0.5 multiplied by -0.0405). The coefficient is also negative when we restrict the sample only to non-exporting enterprises in columns (5) and (6).[12]

Skill Intensity A commonly used indicator of firm quality is skill intensity. Unfortunately, we only observe details on the composition of the work force in the 2004 survey. We use this 2004 cross-section to measure sectoral skill intensity and then test whether tariff cuts prompted firms to switch to skill-intensive sectors.

We define skilled workers as those who have completed a senior-high degree, or a three- or four-year college degree.[13] We calculate the share of skilled workers in the total labor force of each sector in 2004 and rank sectors according to skill intensity. There are 450 sectors in the data. The least skill-intensive sector is the production of packaging and bags, and the most skill intensive sector is a subsector in aircraft manufacturing.

Table 3 presents the results from regression (1) where the dependent variable is sectoral rank, with highest indicating most skill-intensive. The first two columns report

[12] The coefficients in the OLS specifications are all small and statistically insignificant. This result may occur if firms introduce new goods in response to the large tariff cuts of the WTO accession but not to smaller tariff cuts in other years.

[13] Changing the educational cutoffs in the definition of skill intensity yields highly correlated measures.

Table 2: Introduction of New Goods

dependent variable →	All enterprises, excluding SOEs and Multinationals				Only Non-Exporters	
	new product share	new product share	0-1 dummy for introducing a new product	0-1 dummy for introducing a new product	new product share	0-1 dummy for introducing a new product
	OLS	IV	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.000356	-0.0157**	-0.000687	-0.0405**	-0.00976**	-0.0279***
	(0.0012)	(0.0068)	(0.0029)	(0.0168)	(0.0045)	(0.0102)
downstream_tariff	-0.00372	-0.0272	0.00777	-0.0533	-0.0313**	-0.0423
	(0.0024)	(0.0184)	(0.0078)	(0.0399)	(0.0147)	(0.0266)
upsrteam_tariff	0.00251	0.033	-0.0016	0.103*	0.0404**	0.0893**
	(0.0037)	(0.0274)	(0.0092)	(0.0622)	(0.0186)	(0.0382)
index_subsidy	0.00631***	0.00635***	0.0170***	0.0171***	0.00449***	0.0116***
	(0.0008)	(0.0008)	(0.0016)	(0.0016)	(0.0008)	(0.0014)
index_tax	-0.000694*	-0.000663*	-0.00213**	-0.00204**	-0.000451	-0.00145**
	(0.0004)	(0.0004)	(0.0009)	(0.0009)	(0.0004)	(0.0007)
index_interest	-0.00183***	-0.00177***	-0.00617***	-0.00600***	-0.000943**	-0.00347***
	(0.0004)	(0.0004)	(0.0010)	(0.0010)	(0.0004)	(0.0008)
exportshare_sector	-0.0128	0.00461	-0.00328	0.0322	-0.00341	-0.0189
	(0.010)	(0.013)	(0.025)	(0.029)	(0.011)	(0.023)
State_share	0.000525	0.000416	0.00616*	0.00597	0.000107	0.00287
	(0.0020)	(0.0020)	(0.0037)	(0.0037)	(0.0021)	(0.0036)
Horizontal FDI	0.0314***	0.0229*	0.0249	-0.00632	0.0227**	0.0237
	(0.011)	(0.014)	(0.027)	(0.034)	(0.011)	(0.023)
Downstream FDI	-0.00932	0.0266	-0.0532	0.0261	0.0454	0.0152
	(0.024)	(0.039)	(0.058)	(0.086)	(0.033)	(0.060)
Upstream FDI	-0.00705	-0.0285**	-0.0175	-0.0706***	-0.0272***	-0.0540***
	(0.006)	(0.011)	(0.013)	(0.025)	(0.009)	(0.018)
Observations	1,037,738	1,037,738	1,037,738	1,037,738	826,072	826,072
F statistic, log(output tariff) = log(downstream tariff)	1.7	0.5	1.1	0.1	2.6	0.4
First Stage F, output tariff	-	340.7	-	340.7	447.8	447.8
First Stage F, downstream tariff	-	631.1	-	631.1	469.4	469.4
First Stage F, upstream tariff	-	192.6	-	192.6	220.3	220.3

Standard errors are clustered by firm and initial sector. All specifications include firm fixed effects and time effects. Instruments in the IV specifications for log of output tariff, downstream tariff, and upstream tariff include the WTO dummy interacted with the initial tariff. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table 3: Movements to Sectors with Higher Skilled Worker Share Based on 2004 survey

Dependent variable: Ranking of sector according to skill intensity

	All Enterprises, Excluding SOEs and Multinationals		Only Non-Exporters	
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
output_tariff	-17.82***	-26.20***	-18.80***	-19.27***
	(1.00)	(3.81)	(0.89)	(3.14)
downstream_tariff	6.914***	-33.44***	5.907***	-31.39***
	(1.34)	(7.40)	(1.31)	(7.49)
upsrteam_tariff	34.04***	108.5***	36.85***	93.35***
	(2.79)	(14.39)	(2.75)	(13.07)
index_subsidy	0.630***	0.703***	0.843***	0.877***
	(0.16)	(0.18)	(0.19)	(0.20)
index_tax	0.134	0.153	0.216**	0.173*
	(0.09)	(0.10)	(0.10)	(0.10)
index_interest	-0.390***	-0.338***	-0.431***	-0.428***
	(0.110)	(0.115)	(0.123)	(0.127)
exportshare_sector	-194.7***	-185.5***	-209.2***	-202.1***
	(8.64)	(7.80)	(7.81)	(7.98)
State_share	-0.194	-0.0456	-0.423	-0.207
	(0.420)	(0.424)	(0.467)	(0.468)
Horizontal FDI	68.07***	44.12***	73.68***	55.40***
	(7.60)	(9.77)	(7.54)	(9.29)
Downstream FDI	539.2***	592.5***	549.8***	593.3***
	(23.83)	(27.49)	(26.15)	(29.35)
Upstream FDI	-33.38***	-46.95***	-43.23***	-51.02***
	(5.58)	(6.24)	(5.89)	(6.51)
Observations	1,037,738	1,037,738	826,072	826,072
F statistic log(output tariff) = log(downstream tariff)	216	1	228	3
First Stage F, output tariff	-	341	-	448
First Stage F, downstream tariff	-	631	-	469
First Stage F, upstream tariff	-	193	-	220

Sectors with a higher rank (number) are more skill intensive. Standard errors are clustered by firm and initial sector. All regressions include firm fixed effects and time fixed effects.

coefficients for all firms, and the last two columns include only non-exporting firms. Since all specifications include firm fixed effects, the identification stems from firms switching sectors. Approximately 15 percent of firms in the sample change sectoral affiliation over the period from 1998 to 2007.

The coefficient on output tariffs is consistently negative and significant. A decline in output tariffs is thus associated with a movement to skill-intensive sectors. The point estimates, ranging from -18 to -26, imply that a one standard deviation reduction in log tariffs (around .5) is associated with a movement up the rank that ranges between 9 and 13 sectors. Among non-exporting firms, the sector switches with the largest number of firms include switches from cotton and chemical fibers (1761) to textile and garments manufacturing (1810), and from steel rolling processing (3230) to the manufacture of metal structures (3411), from non-ferrous rolling process (3351) to optical fiber and cable manufacturing (3931). In all cases, these switches are from lower value-added products or stages of production to higher value-added products, where the scope for differentiation is arguably greater. They are thus consistent with our thesis that firms escape import competition by differentiating their products.

Firm Heterogeneity Table 4 investigates whether the responses to tariff cuts differ across firms of different sizes. We split firms in each sector-year into quartiles of sales, and we repeat regression (1) replacing the main independent variable of interest *output_tariff* with *output_tariff* interacted with dummies of whether the firm is in quartile $q = 1, ..., 4$ of sales within its sector-year. The dependent variables are TFP, introduction of new goods, and the ranking of skill-intensive sectors as in Tables 1, 2, and 3.

Table 4 reports only the coefficients of interest.[14] The dependent variable in Panel B measures the introduction of new goods, and in Panel C, it is the ranking of sectoral skill-intensity. In all specifications of Panels B and C, the coefficients on output tariffs are very similar across quartiles of firm sales. In contrast in Panel A where the dependent variable is TFP, the coefficient on output tariffs increases systematically with quartile of sales, and the differences are statistically significant. In response to tariff cuts, the TFP of small firms *increases* while the TFP of large firms *decreases*.

Downstream Tariffs In all IV specifications, the coefficient on downstream tariffs in Tables 1, 2 and 3 are negative and equality with the coefficient on output tariffs cannot be rejected. In the OLS specification, the coefficient on downstream tariffs is generally

[14] See Appendix A.4 for other coefficients. The coefficients on the other two tariff measures practically do not change from Tables 1, 2, and 3.

Table 4: Heterogeneous responses of firms to output tariff cuts

Panel A: Dependent variable is TFP à la Olley-Pakes or OLS with fixed effects (FE)

	All firms excluding SOEs and multinationals				Only non-exporters	
	OP OLS	FE OLS	OP IV	FE IV	OP IV	FE IV
output_tariff*q1	-0.108***	-0.112***	-0.0975***	-0.0966***	-0.115***	-0.114***
	(0.00279)	(0.00291)	(0.0162)	(0.0174)	(0.0147)	(0.0154)
output_tariff*q2	-0.0607***	-0.0639***	-0.0408**	-0.0377**	-0.0554***	-0.0515***
	(0.00266)	(0.00278)	(0.0161)	(0.0173)	(0.0146)	(0.0153)
output_tariff*q3	-0.0159***	-0.0173***	0.0187	0.0245	0.00770	0.0146
	(0.00259)	(0.00271)	(0.0160)	(0.0172)	(0.0145)	(0.0152)
output_tariff*q4 (largest)	0.0385***	0.0398***	0.0950***	0.105***	0.0871***	0.0982***
	(0.00261)	(0.00273)	(0.0161)	(0.0173)	(0.0145)	(0.0153)
Observations (panels A, B, C)	1,037,738	1,037,738	1,037,738	1,037,738	826,072	826,072

Panel B: Dependent variable is a measure of introduction of new goods

	All firms excluding SOEs and multinationals				Only non-exporters	
dependent variable →	new product share OLS	0-1 dummy for new product OLS	new product share IV	0-1 dummy for new product IV	new product share IV	0-1 dummy for new product IV
output_tariff*q1	-0.000914	-0.00566**	-0.0160**	-0.0438***	-0.0103**	-0.0300***
	(0.00119)	(0.00287)	(0.00679)	(0.0167)	(0.00447)	(0.0102)
output_tariff*q2	-0.000700	-0.00262	-0.0156**	-0.0396**	-0.00966**	-0.0276***
	(0.00121)	(0.00290)	(0.00677)	(0.0167)	(0.00445)	(0.0101)
output_tariff*q3	-0.000557	-0.000705	-0.0153**	-0.0369**	-0.00940**	-0.0261***
	(0.00122)	(0.00292)	(0.00675)	(0.0167)	(0.00442)	(0.0101)
output_tariff*q4 (largest)	0.000522	0.00446	-0.0138**	-0.0301*	-0.00895**	-0.0227**
	(0.00123)	(0.00298)	(0.00672)	(0.0167)	(0.00445)	(0.0101)

Panel C: Dependent variable is the sector ranking in skill intensity (higher ranking corresponds to greater skill intensity)

	All firms excluding SOEs and multinationals		Only non-exporters	
	OLS	IV	OLS	IV
output_tariff*q1	-7.631***	-12.40***	-8.445***	-10.50***
	(0.854)	(2.532)	(0.778)	(1.970)
output_tariff*q2	-7.582***	-12.33***	-8.375***	-10.41***
	(0.856)	(2.526)	(0.781)	(1.966)
output_tariff*q3	-7.650***	-12.29***	-8.435***	-10.39***
	(0.864)	(2.531)	(0.788)	(1.968)
output_tariff*q4 (largest)	-7.561***	-12.04***	-8.340***	-10.18***
	(0.864)	(2.531)	(0.788)	(1.967)

The table repeats the results of Table 1 through 3, substituting the independent variable output_tariff for an interaction of output_tariff with a dummy indicating the firm's quartile of sales in period $t-1$ (q1, q2, q3, q4). Only the coefficients on the interaction terms are reported, but the regressions include the same other independent variables as the previous tables. Appendix A.4 reports the coefficients on the other control variables.

statistically insignificant and at times flips sign. These results suggest that, in response to tariff cuts, the suppliers of inputs to import-competing firms introduce new goods and switch to skill-intensive sectors, though plausibly to a smaller extent than the import-competing firms, directly hit with the shock.

In contrast, when the dependent variable is TFP in Table 1, the coefficients on downstream tariffs are about seven times larger than the coefficients on output tariffs in all IV specifications. This result is robust to numerous checks in Section 6, and Section 5 introduces intermediate inputs to the model to explain it.[15]

2.4 Empirical Findings and Existing Models

Tables 1, 2, and 3 above suggest that tariff cuts lead import-competing firms to increase revenue TFP, introduce new goods, and shift toward skill-intensive activities. These results are broadly in line with the prevailing view among policy makers that import competition enhances firm performance, but they are difficult to reconcile with existing models of international trade.

In a large class of models in international trade, firms endogenously invest in higher technologies when their sales increase, e.g., Bustos (2011), Caliendo and Rossi-Hansberg (2012), Helpman et al. (2017). In these models, import competition decreases sales and investments in technologies among non-exporting firms. In contrast in the data, import competition increases TFP (Table 1) within firms, especially among non-exporting firms.[16] Similarly, in trade models with variable markups, such as Bernard et al. (2003), Melitz and Ottaviano (2008), Atkeson and Burstein (2008), import competition decreases sales and markups within firms. In all these models, import competition may increase average productivity or markups through selection, the exit of the least productive firms, but our regression specification, with firm fixed effects, captures within-firm changes.

The introduction of new goods challenges recent models of multiproduct firms, such as Bernard et al. (2011) and Mayer et al. (2014). In these models, firms respond to tighter competition by dropping their least productive varieties, not introducing new ones.

[15] Differences between TFP and other outcomes appear also in the coefficients on upstream tariffs. The large response of TFP to upstream tariffs could be due to increases in markups as in DeLoecker et al. (2016). Still, the Chinese government has many programs to reimburse input tariffs, and so our upstream tariff measure may not capture the actual trade barriers faced by firms importing inputs. This point may explain the unexpected sign of the coefficient on upstream tariffs in Tables 2 and 3. See Brandt et al. (2017) for similar points on measuring upstream tariffs in China.

[16] Appendix A.3 analyzes the relation between revenue and TFP. As in other data sets, Table A.11 confirms that TFP and revenue are correlated, even after controlling for time and sector fixed effects. And Table A.12 confirms that tariff cuts are associated with decreases in sales. These patterns are consistent with the models above.

Although the classic Heckscher-Ohlin model predicts that trade shifts production across sectors, it predicts shifts toward unskill-intensive sectors in an unskill-abundant country like China, the opposite direction of the shifts in Table 3. Recent models predict that trade may increase the demand for skills even in developing countries.[17] These models operate through export expansion or imported inputs and capital. But our empirical results exploit variations in tariffs imposed by China, and they hold even when the sample is restricted to non-exporters, suggesting that import competition also plays a role.

We interpret the findings on new goods and shifts to skill-intensive sectors as evidence that firms engage in product innovation in response to import-competition. Section 3 presents a simple model where import competition increases product innovation. Although it would be simple to add skills to the model, we do not add it to keep the focus on innovation. To address TFP results, a measure of the ratio of revenue to cost (equation (2)), we base our setup on a model of variable markups, Atkeson and Burstein (2008).

3 Theory

The empirical results above pertain to import competition and exploit cross-sectoral variation. Accordingly, we analyze the behavior of non-exporting firms in partial equilibrium. There is a continuum of sectors, and we study a fixed and finite set of firms in one sector. Section 4 extends the set up to general equilibrium.

Firms with heterogeneous productivities compete à la Bertrand. Each firm has a unique variety. It may exit or pay a fixed cost to produce. If the firm produces, it chooses between two levels of differentiation. Less-differentiated varieties face a higher price elasticity of demand but have lower (fixed or variable) costs than more differentiated varieties. To avoid cumbersome language, we refer to more-differentiated varieties as "differentiated," even though the elasticity of demand is finite for all varieties. This choice of differentiation is the only departure from the simplest version of Atkeson and Burstein (2008). To highlight it, we initially do not distinguish between domestic and foreign firms. Foreign firms are introduced in Section 3.2. All proofs are in Appendix B.

[17] See Feenstra and Hanson (1997), Yeaple (2005), Burstein and Vogel (2016), Burstein et al. (2016), Helpman et al. (2017), Lee (2018), and Fieler et al. (2018).

Demand Spending on a variety with price p in nest n follows a nested CES demand system:

$$x(p) = \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{1-\sigma} y \tag{3}$$

$$\text{where} \quad P_n = \left[\sum_{i \in n} p_i^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{4}$$

$$\overline{P} = \left[\int_{\mathcal{N}} P_n^{1-\eta} dn \right]^{\frac{1}{1-\eta}}, \tag{5}$$

y is consumer spending, P_n is the price index of nest n, $\mathcal{N}$ is the set of nests, and $\overline{P}$ is the overall price index. The elasticity of substitution is η between nests and σ between varieties within a nest, where $\sigma > \eta > 1$.

There are two types of nests. Nest $\mathcal{O}$ contains all less-differentiated varieties. When a firm has a differentiated variety, it is the single producer in its own nest. Then, $P_n = p$ and demand reduces to $x = (p/\overline{P})^{1-\eta}$. Subscript 0 refers to less-differentiated varieties and D refers to differentiated varieties. There is a continuum of nests. We take y, $\mathcal{N}$, and $\overline{P}$ as exogenous since a finite set of firms cannot affect them. They are determined in general equilibrium in Section 4.

Technology If the firm exits, its profit is zero. Production requires a fixed cost f_0 if the firm is less differentiated and f_D if the firm is differentiated. Firm i's unit cost is c_{i0} if the firm is not differentiated and c_{iD} if the firm is differentiated. As in Melitz (2003), unit costs are adjusted for quality and the model has no predictions for quantity TFP. Product differentiation is a nontrivial decision for firm i if $c_{iD} > c_{i0}$ or $f_D > f_0$ (or both).

Equilibrium There is an exogenous set of potentially active firms, each with its unit costs (c_{i0}, c_{iD}).[18] In ascending order of cost c_{i0}, each firm decides among three discrete choices: (i) To exit, (ii) to produce a less differentiated variety, or (iii) to produce a differentiated variety. Once all discrete choices are made, firms simultaneously set prices. We consider the subgame perfect equilibrium.[19]

[18]One can think of this assumption as allowing for free entry and firm knowledge about their productivity prior to entry. Appendix D.2 introduces free entry to the general equilibrium model.

[19]The timing of firms' discrete choices according to productivity is a standard equilibrium selection mechanism, in Atkeson and Burstein (2008), Edmond et al. (2015).

3.1 Equilibrium Characteristics

The equilibrium is solved by backward induction. Consider first the price decisions and payoffs after all discrete choices are made. Firm i in nest n with unit cost c_i chooses price p to maximize operating profit

$$\pi = \max_p \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma}(p - c_i)y \tag{6}$$
$$\text{subject to} \quad P_n = \left(\sum_{i' \in n, i' \neq i} p_{i'}^{1-\sigma} + p^{1-\sigma} \right)^{1/(1-\sigma)} .$$

The firm best responds to the prices of other firms in its nest. Following Atkeson and Burstein (2008), the markup over marginal cost is $\epsilon/(\epsilon - 1)$ where

$$\epsilon = \sigma(1 - s) + \eta s, \tag{7}$$
$$s = \left(\frac{p}{P_n} \right)^{1-\sigma}$$

The endogenous elasticity of demand ϵ is a weighted average between the elasticity in the nest σ and the elasticity across nests η, where the weight s is the market share of the firm measured in revenue. If the variety is differentiated, $P_n = p$, $s = 1$ and demand elasticity is η. Given a vector of unit costs in the less-differentiated nest $\{c_{i0}\}_{i \in \mathcal{O}}$, equation (7) implicitly defines the price for each firm in $\mathcal{O}$. Denote with $\epsilon_0(\mathbf{c}_{-i0}, c_{i0})$ the equilibrium elasticity of demand of a less-differentiated firm with unit cost c_{i0} when the vector of its competitors' costs is $\mathbf{c}_{-i0}$, and $P_0(\mathbf{c}_0)$ as the equilibrium price index in (3) where $\mathbf{c}_0$ is the vector of unit costs in nest $\mathcal{O}$.

Using this pricing rule and unit costs, the operating profit of firm i with and without product differentiation is, respectively, (equation (6))

$$\pi_D(c_{iD}) = \frac{\overline{P}^{\eta-1}}{\eta} \left(\frac{\eta c_{iD}}{\eta - 1} \right)^{1-\eta} y,$$
$$\pi_0(\mathbf{c}_{-i0}, c_{i0}) = \overline{P}^{\eta-1} \frac{[P_0(\mathbf{c}_0)]^{\sigma-\eta}}{\epsilon_0(\mathbf{c}_{-i0}, c_{i0})} \left(\frac{[\epsilon_0(\mathbf{c}_{-i0}, c_{i0})]c_{i0}}{\epsilon_0(\mathbf{c}_{-i0}, c_{i0}) - 1} \right)^{1-\sigma} y. \tag{8}$$

The profit with differentiation depends only on the firm's own unit cost c_{iD}. The profit without differentiation also depends on the vector of unit costs of the firm's competitors in the less-differentiated nest, $\mathbf{c}_{-i0}$, through P_0 and ϵ_0.

Order the m firms so that $c_{10} < c_{20} < ... < c_{m0}$. Denote an action of firm i with $g_i \in \{$*exit*, *less differentiation*, *differentiation*$\}$. A vector of actions $\mathcal{G} = (g_1, ..., g_m)$ determines the sets of exiting, less-differentiated, and differentiated firms. The payoffs for any $\mathcal{G}$ are in (8). The full game can be solved by backward induction starting with the least productive firm m and moving up the game tree. For each $i = m, ..., 1$ and all possible set of actions $(\tilde{g}_1, ..., \tilde{g}_{i-1})$, firm i chooses among three subgames with starting nodes $(\tilde{g}_1, ..., \tilde{g}_{i-1}, g_i)$ for $g_i =$ *exit*, *less differentiation*, *differentiation*. These decisions are unique in every node of the game tree up to a perturbation of parameters. So, the subgame perfect equilibrium is also unique up to a perturbation of parameters. Throughout, we ignore these indifference cases and cases in which two or more firms have the same unit cost c_{i0} or c_{iD}.

Proposition 1 ***Exit.*** *Suppose that firms can be ranked in terms of costs, $c_{iD} < c_{i'D}$ if and only if $c_{i0} < c_{i'0}$. Then, there exists $\tilde{c} > 0$ such that firms produce if and only if $c_{i0} \leq \tilde{c}$. Cutoff $\tilde{c}$ is increasing in $\overline{P}$.*

Although the decision to exit seems standard, the proof in Appendix B hinges on the assumption that more productive firms make their discrete choices first. Otherwise, the entry of a less-productive firm could drive down the price index sufficiently to prevent the entry of a more productive firm.

A firm's decision to differentiate its product, in turn, is generally not monotonic in costs. Proposition 2 characterizes it as a function of its productivity and the competition it faces in a subgame, captured by $\mathbf{c}_{-i0}$. For the subgame perfect equilibrium, the relevant vector of competitors' costs, denoted with $\hat{\mathbf{c}}_{-i0}$, is the one in the outcome of the subgame starting with $\{\hat{g}_1, ..., \hat{g}_{i-1}, \textit{less differentiation}\}$, where $\hat{g}_{i'}$ denotes the action of firm i' in the equilibrium path.

Proposition 2 ***Product differentiation.*** *Fix $\mathbf{c}_{-i0}$ and the ratio of unit costs c_{iD}/c_{i0}. If the set of firm productivity parameters $\phi_i \equiv (c_{i0})^{-1}$ such that firm i differentiates its product is non-empty, then (i) it is a line segment $[\underline{\phi}, \overline{\phi}]$ if differentiation increases unit costs $c_{Di}/c_{0i} \geq 1$, and (ii) it is unbounded if differentiation decreases unit costs $c_{Di}/c_{0i} < 1$.*

The gross gain from product differentiation $\pi_D(c_{iD}) - \pi_0(\mathbf{c}_{-i0}, c_{i0})$ strictly increases if $\mathbf{c}_{-i0}$ decreases or if $\mathbf{c}_{-i0}$ is augmented with new elements (competitors).

To isolate the novel gain of product differentiation from changes in unit costs, consider the special case $c_{iD} = c_{i0} \equiv c_i$. We show that the net gain from differentiation, $\pi_D(c_i) - \pi_0(\mathbf{c}_{-i0}, c_i)$, tends to zero as the firm's own cost c_i tends to zero or infinity. From equation (8), $\lim_{c_i \to \infty} \pi_0(\mathbf{c}_{-i0}, c_i) = \lim_{c_i \to \infty} \pi_D(c_i) = 0$. For the other limit, let $p_{iD} = \eta c_i/(\eta - 1)$ be the price of the differentiated variety, and P_{-i0} be the CES price index in nest $\mathcal{O}$

excluding firm i for the given $(\mathbf{c}_{-i0}, c_i)$.[20] Then

$$\begin{aligned}
\pi_D(c_i) &= \frac{y\overline{P}^{\eta-1}}{\eta} p_{iD}^{1-\eta} \\
&\leq \frac{y\overline{P}^{\eta-1}}{\eta} \left(P_{-i0}^{1-\sigma} + p_{iD}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-i0}^{1-\sigma} + \frac{y\overline{P}^{\eta-1}}{\eta} \left(P_{-i0}^{1-\sigma} + p_{iD}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} p_{iD}^{1-\sigma} \\
&\leq \frac{y\overline{P}^{\eta-1}}{\eta} \left(P_{-i0}^{1-\sigma} + p_{iD}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-i0}^{1-\sigma} + \pi_0(\mathbf{c}_{-i0}, c_i)
\end{aligned}$$

In the second line is the operating profit of a hypothetical, differentiated firm that charges $\left[P_{-i0}^{1-\sigma} + p_D^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \leq p_{iD}$ and gets a share $1/\eta$ of revenue as profits. The third line comes from profit maximization of the less-differentiated firm. Both inequalities hold strictly if $P_{-i0} < \infty$. Rearranging and taking limits,

$$\lim_{c_i \to 0} \left[\pi_D(c_i) - \pi_0(\mathbf{c}_{-i0}, c_i)\right] \leq \lim_{p_{iD} \to 0} \frac{y\overline{P}^{\eta-1}}{\eta} \left(P_{-i0}^{1-\sigma} + p_{iD}^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-i0}^{1-\sigma} = 0$$

In words, without unit cost changes, $c_{i0} = c_{iD}$, the gain in operating profit from differentiation is bounded above by the profit of acquiring the residual demand of competitors in nest $\mathcal{O}$. Since this residual demand goes to zero as the firm's own cost c_i goes to zero, the gain from differentiation also goes to zero.[21]

Figure 1 illustrates the gain from product differentiation net of fixed costs (panel A) and markups (panel B) as a function of the inverse of the firm's unit cost when $c_{iD} = c_{i0}$ and $f_D > f_0$, for a given $\mathbf{c}_{-i0}$. If the firm is sufficiently unproductive, then the firm does not differentiate its product because sales are too small to recoup fixed cost $(f_D - f_0)$. If the firm is much more productive than its competitors, it practically has a monopoly in nest $\mathcal{O}$ and does not have an incentive to pay a fixed cost to further differentiate its product. This result is consistent with the case studies surveyed by Holmes and Schmitz (2010), where monopolists charge high prices for inferior products, and with evidence of a non-monotonic effect of productivity on innovation in Aghion et al. (2005), Aghion and

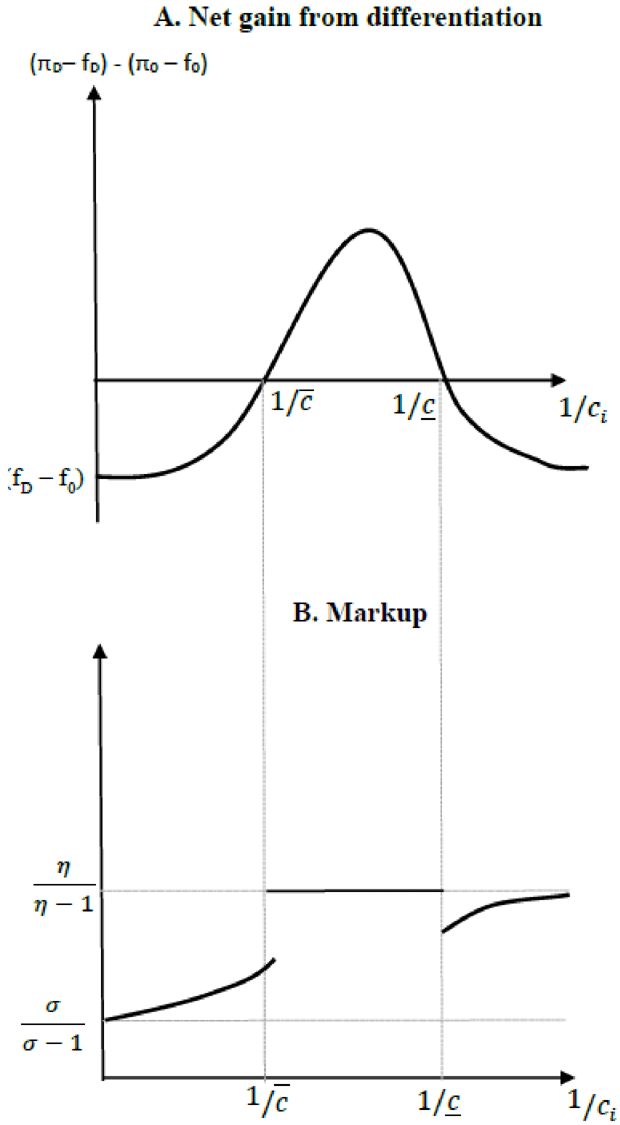
[20]

$$P_{-i0} = \left(\sum_{i' \neq i, i' \in \mathcal{O}} p_{i'}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

where prices $p_{i'}$ are implicitly defined in (7) when the productivity vector in $\mathcal{O}$ is $(\mathbf{c}_{-i0}, c_i)$.

[21]The claim $\lim_{c_i \to 0}(\pi_D - \pi_0) = 0$ is trivial in the limit when $\sigma = \infty$ and goods are homogeneous within nest $\mathcal{O}$ as in Bernard et al. (2003). Then, the price is the minimum between the second lowest cost or the monopoly price $p_{iD} = \eta c_i/(\eta - 1)$. For sufficiently high productivity, the firm's profit in nest $\mathcal{O}$ is constant and equal to the case where it differentiates its product. We thank Samuel Kortum for pointing out this case.

Figure 1: Gains from product differentiation and markups when $c_{iD} = c_{i0} = c_i$



Griffith (2008), and Spearot (2013).[22]

The last statement of Proposition 2 formalizes the effect of escaping competition. For any c_{iD} and c_{i0}, the gains from product differentiation increases when $\mathbf{c}_{-i0}$ decreases or is augmented with new elements. In Appendix D1, this result holds when the fixed cost of creating new nests depends on the number of existing nests because it is increasingly difficult to find new market ideas, and it holds when there is imitation if the shock to competition is sufficiently large.

[22] It is difficult to measure this non-monotonicity in the cross-section of our data, without directly observing product differentiation. Table 4 does not present evidence of a non-monotonic response to import competition. As discussed below, this finding does not necessarily contradict the model.

3.2 Foreign Firms

To interpret the empirical results from Section 2, we introduce foreign firms to the model. In the definition of the equilibrium above, assume that a subset of firms, foreign firms, do not make discrete choices. They have pre-assigned nests and only enter the final stage of the game in which prices are set. Their unit costs are exogenous and known, and at least some foreign firms are in the less-differentiated nest $\mathcal{O}$.

The key underlying assumption is that shocks to foreign costs disproportionately affect the profit of less-differentiated domestic firms. This assumption appears counterintuitive in our empirical application to China, a developing country importing goods mostly from developed countries. But following the anecdotes of Chery and Xiaomi in the introduction, domestic firms differentiate their products by bundling them with non-tradable services, catering to domestic tastes, and offering greater customization. The equilibrium is unaltered by the existence of a finite set of differentiated foreign firms, i.e., of market niches with only foreign firms, such as luxuries or high-tech goods. And allowing foreign firms to exit does not affect the results below, which refer to large decreases in foreign costs.

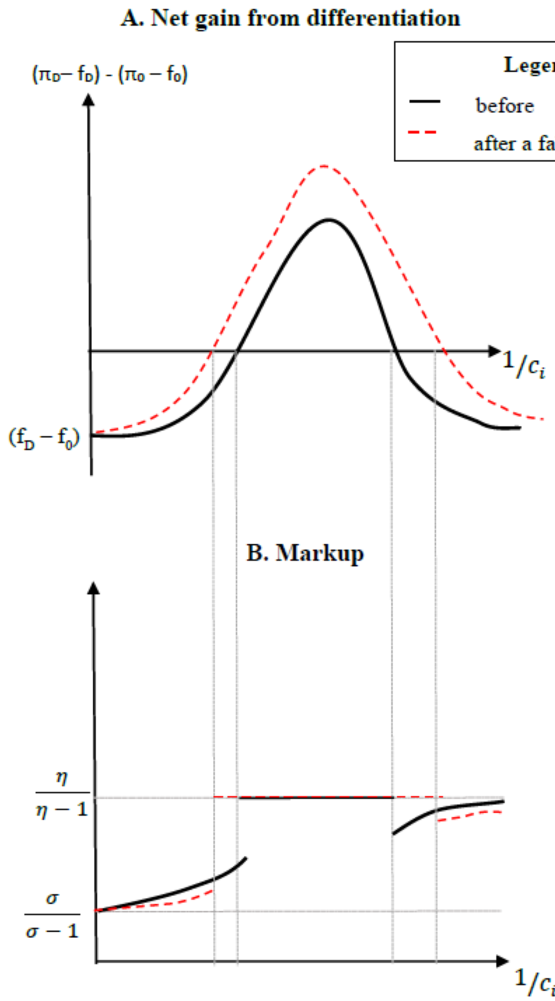
Propositions 3 and 4 below analyze how the subgame perfect equilibrium changes when we shock the economy with a decrease in foreign costs. Such a decrease may occur through the cost of individual varieties or an expansion of varieties. The shock has to be sufficiently large for competition to tighten in the differentiated nest for all firms, i.e., for the subgame perfect equilibrium $P_{-i0}(\hat{\mathbf{c}}_{-i0}, c_{i0})$ to decrease for all i. A large shock satisfies this condition because, in any subgame and for any firm i, $P_{-i0}(\mathbf{c}_{-i0}, c_{i0})$ is smaller than the price index P_0 in the subgame without domestic firms in nest $\mathcal{O}$.

Proposition 3 ***Import competition.*** *A sufficiently large decrease in foreign costs increases exit and product differentiation among surviving firms. The markup increases for firms that differentiate their products, and it decreases for other firms.*

Proposition 3 follows from Proposition 2 and from the price equation (7).[23] Figure 2 illustrates effect of the shock when $c_{i0} = c_{iD}$ and $f_0 < f_D$. The solid black curves are the same as in Figure 1, and the dashed red line indicates the equilibrium after the shock. In Figure 2A, the gain from differentiation increases because the shock decreases profit

[23] To see why the statement of the proposition breaks down for small decreases in foreign costs, consider an example with two firms. Before the liberalization, the more productive firm differentiates because it cannot deter the entry of the second firm into nest $\mathcal{O}$ if it does not differentiate. As foreign prices decrease, the first firm may choose not to differentiate because it deters the entry of the second firm into nest $\mathcal{O}$. Then, firm 1 shifts from a differentiated to a less-differentiated variety contrary to the proposition. In this example, however, the decrease in foreign cost is not sufficiently large. Price index $P_{-10}(\hat{\mathbf{c}}_{-10}, c_{10})$ increases as firm 2 leaves nest $\mathcal{O}$, either by not producing or differentiating.

Figure 2: Effect of import competition on differentiation and markups when $c_{iD} = c_{i0} = c_i$



π_0 and has no effect on π_D. In Figure 2B, the markup increases to $\eta/(\eta - 1)$ for newly differentiated firms, and it decreases for firms that remain less-differentiated.

The shock to the Chinese market during the period of its WTO accession was large. Imports as a share of GDP in China rose from 14 percent in 1998 to 28 percent in 2006. Tables 2 and 3 suggest that, in response to tariff cuts, Chinese firms introduce new varieties and switch to more skill-intensive sectors. We interpret these results as evidence of increases product differentiation. The introduction of new varieties is a natural proxy for differentiation. Some of the most common sectoral switches in the data are to sectors with a greater scope for differentiation, e.g., from cotton and chemical fibers to textile and garments manufacturing, and from steel rolling processing to metal structures. In addition, product differentiation may increase skill-intensive activities within firms even in a developing country like China. To offer greater variety and customization of car features, for example, Chery Automobile invested in research and development, and in skill-biased technologies such as modern machinery and integrated computer systems. The cell phone company Xiaomi designed new software for Chinese usage. While many of these task changes occur within sectors, some may imply a switch in the firm's four-digit sectoral classification.

According to Proposition 3, import competition has an ambiguous effect on markups, even though it unambiguously increases differentiation among import-competing firms. In our data, output tariff cuts are associated with increases in revenue TFP (Table 1), but markups may explain the mixed evidence of the effects of tariff cuts on firm productivity in the literature despite the commonplace view that trade improves the performance of import-competing firms.[24]

Proposition 4 ***Heterogeneous firms*** *Consider the effect of a sufficiently large decrease in the cost of foreign varieties on two domestic firms, a and b, originally producing less-differentiated varieties with* $c_{a0} < c_{b0}$*. If both firms a and b differentiate their products in response to the shock, the markup increase is larger for firm b than firm a. If both firms remain less-differentiated, the percentage decrease in firm b's markup is smaller (in absolute value) than firm a's.*

Within the same nest, markups are decreasing in firms' costs. Since the markups of firms a and b increase to $\eta/(\eta-1)$ if they both differentiate their products, the markup change is larger for the higher-cost firm. The proof of the case in which both firms remain less-differentiated is in Appendix B, and it takes into account that firms a and b experience the original shock differently because they best respond to each other's markups. We only note that small firms have little scope for decreasing markups that are already close to the lower bound $\sigma/(\sigma-1)$.

Proposition 4 refers to heterogeneous firms. The model has no sharp predictions regarding the size of firms that should differentiate when import competition tightens. Figure 2 holds in the special case $c_{i0} = c_{iD}$ and $f_D > f_0$, for a given $\mathbf{c}_{-i0}$. In response to import competition in the model, a large firm that loses its monopoly of the less-differentiated nest may differentiate its output as well as a small firm if differentiation does not require large fixed costs, $c_{iD} > c_{i0}$ and $f_D \approx f_0$. In addition, Appendix B shows that the set of firms differentiating their products in equilibrium need not be convex in unit costs even when $c_{i0} = c_{iD}$ for all firms i, since $\hat{\mathbf{c}}_{-i0}$ is firm specific.

Proposition 4 predicts that, when foreign costs fall, the markups of large, low-cost firms decrease relative to smaller firms' markups *if these firms react similarly in terms of product differentiation*. It is relevant because, in Panels B and C of Table 4, firms in

[24]See references in footnote 1.

all quartile of sales have a similar propensity to introduce new goods or switch to skill-intensive sectors in response to tariff cuts. If we again take these variables as proxies for differentiation, then the model predicts that the coefficient on output tariffs should increase systematically with quartile of firm sales when the dependent variable is TFP, an estimate of the ratio of revenue to cost. Table 4A confirms this prediction.[25]

Our empirical results on revenue TFP are suggestive but cannot be taken as evidence for the model, because the model violates the assumptions underpinning measures of productivity and markups in the literature. Assumptions of a Markov path for productivity, Hicks neutrality, and product homogeneity are all violated in the model and arguably in the data as import competition reshapes firms' residual demand and innovation changes output and production processes. Still, the coincidence between our predictions on markups and movements in measured productivity in the data, even when these predictions differ from movements in other firm outcomes, suggests caution in interpreting productivity measures and other pecuniary firm outcomes during trade liberalization episodes.[26] We used the introduction of new goods and sectoral-switching as more direct proxies for differentiation.

4 General Equilibrium and Welfare

The partial equilibrium model rationalizes the evidence of Section 2 on the effects of tariff cuts on product innovation and revenue productivity. We now extend it to general equilibrium to analyze welfare. The set up is in Section 4.1 and the results are in Section 4.2. We model a small open economy with an exogenous set of firms. Appendix D.2 introduces free entry, and Appendix D.3 models two large and symmetric countries.[27]

[25]Pro-competitive effects on prices are larger for large firms also in Amiti et al. (2014) and Edmond et al. (2015).

[26]It is well known that revenue TFP captures efficiency and prices, and the literature has made progress in disentangling markups from efficiency gains. As Foster et al. (2008) explain, these methods apply to sectors with homogeneous goods, where TFPQ is meaningful. Harrison (1994), De Loecker (2007) and De Loecker and Warzynski (2012) make similar points on changes in measured productivity during trade reforms. DeLoecker et al. (2016) propose a measurement that allows for vertically-differentiated goods, but maintain the other assumptions above.

[27]None of the results are affected by free entry. In the two-country model, the welfare results remain but Proposition 7 may change. It assumes a large decrease in foreign costs a decrease in trade costs may not be sufficient.

4.1 General Equilibrium Set Up

We describe Home, a small country that trades with large Foreign. Labor is the only input into production. A representative household inelastically supplies its one unit of labor to a perfect labor market. There is an exogenous continuum of sectors with measure one, denoted with $S \in [0,1]$. Each sector is modelled exactly as in Section 3 and we add sector subscripts S to its variables. Sector S is endowed with a single nest of less-differentiated varieties $\mathcal{O}_S$, and exogenous finite sets of Home and Foreign firms.

Foreign firms are partitioned into a less-differentiated set $\mathcal{O}_{FS}$ and a differentiated set $\mathcal{D}_{FS}$. Less-differentiated firms produce in the less-differentiated nest $\mathcal{O}_{FS} \subset \mathcal{O}_S$, and each differentiated firm $i \in \mathcal{D}_{FS}$ has its own nest. These sets are characterized by vectors of unit costs $\{c_{i0S}\}_{i \in \mathcal{O}_{FS}}$ and $\{c_{iDS}\}_{i \in \mathcal{O}_{FS}}$, which are bounded away from zero and are continuous in S except for at most a finite set of sectors S in which the number of firms in $\mathcal{O}_{FS}$ or $\mathcal{D}_{FS}$ change.

Home firm $i \in S$ chooses to exit the Home market, to supply it with a less-differentiated variety, or to supply it with a differentiated variety following the strategic game in Section 3. If the firm produces a less-differentiated variety, its fixed cost of production is $f_0 = w\tilde{f}_0$ and its unit cost is $c_{i0S} = w\tilde{c}_{i0S}$. If the firm produces a differentiated variety, these costs are respectively $f_D = w\tilde{f}_D$ and $c_{iDS} = w\tilde{c}_{iDS}$, where w is the wage rate, and $\tilde{c}_{i0S}$, $\tilde{c}_{iDS}$, $\tilde{f}_0$, and $\tilde{f}_D$ are exogenous labor requirements. Let m_S be the number of Home firms in sector S, and assume vectors $(\tilde{c}_{10S}, ..., \tilde{c}_{m_S 0S})$ and $(\tilde{c}_{1DS}, ..., \tilde{c}_{m_S DS})$ are bounded away from zero and are continuous in S except for at most a finite number of sectors where m_S changes.

In addition to supplying Home, each Home firm $i \in S$ may export to Foreign. If it exports, it incurs a fixed cost f^* units of labor and gets the following sales and net profits from exporting:

$$
\begin{aligned}
X^*(\tilde{c}_{i0S}) &= (w\tilde{c}_{i0S})^{1-\sigma} Y^*, \\
\pi^*(\tilde{c}_{i0S}) &= \frac{X^*(\tilde{c}_{i0S})}{\sigma} - wf^*
\end{aligned}
\tag{9}
$$

where $Y^* > 0$ is a parameter. The firm exports if and only if $\tilde{c}_{i0S} \leq c^*(w)$, where

$$
c^*(w) = w^{-1} \left(\frac{Y^*}{\sigma w f^*} \right)^{1/(\sigma-1)}.
$$

The assumption that domestic firms do not price strategically in Foreign is only for simplicity. The key assumption is that a firm's decisions to export and to differentiate its product are independent. It is not implausible in our leading example of automobile companies. Chery may provide variety and replacement parts in China, where it owns many production facilities, but not in foreign countries through exports alone.[28]

Suppose all firms in all sectors play the unique subgame perfect equilibrium of Section 3 above given a vector of the wage rate, overall price index, and income $(w, \overline{P}, y)$. Denote with $\mathcal{O}_{HS}$ and $\mathcal{D}_{HS}$ the equilibrium sets of less-differentiated and differentiated domestic varieties respectively. The equilibrium set of less-differentiated varieties in sector S is $(\mathcal{O}_{HS} \cup \mathcal{O}_{FS}) = \mathcal{O}_S$, and of differentiated varieties is $(\mathcal{D}_{HS} \cup \mathcal{D}_{FS}) = \mathcal{D}_S$. Then, the set of all nests in (5) is $\mathcal{N} = \{\mathcal{O}_S \cup \mathcal{D}_S\}_{S \in [0,1]}$ and the price index is

$$\overline{P} = \left[\int_0^1 [P_0(\mathbf{c}_{0S})]^{1-\eta} + \sum_{i \in \mathcal{D}_S} \left(\frac{\eta c_{iDS}}{\eta - 1} \right)^{1-\eta} dS \right]^{1/(1-\eta)} \tag{10}$$

where $P_0(\mathbf{c})$ is the equilibrium price index in a less-differentiated nest with a vector of unit costs $\mathbf{c}$, when firms price according to (7), and $\mathbf{c}_{0S}$ is the vector of unit costs in nest $\mathcal{O}_S$ in the subgame perfect equilibrium. Given the assumptions on boundedness and continuity, these prices $P_0(\mathbf{c}_{0S})$ are continuous in S in all but a zero-measure set of sectors in which $\mathcal{O}_{FS}$, $\mathcal{D}_{FS}$, $\mathcal{O}_{HS}$, or $\mathcal{D}_{HS}$ change exogenously or endogenously through changes in Home firms' discrete choices. Hence, the integral is well defined and continuous in any $(w, \overline{P}, y)$. Integrals in (11) and (12) below have the same properties for the same reasons.

The representative household gets income from labor and profits:

$$y = w + \int_0^1 \left[\sum_{\{i \in S: \tilde{c}_{i0S} \leq c^*(w)\}} \pi^*(\tilde{c}_{i0S}) + \sum_{i \in \mathcal{D}_{HS}} \pi_D(c_{iDS}) + \sum_{i \in \mathcal{O}_{HS}} \pi_0(\mathbf{c}_{-i0S}, c_{i0S}) \right] dS \tag{11}$$

Define $P_{F0}(\mathbf{c}_{0FS}, \mathbf{c}_{0HS})$ as the price index of the less differentiated nest $\mathcal{O}_S$ in (4) where only foreign firms are included in the sum, when the vector of Foreign unit costs is $\mathbf{c}_{0FS} = \{c_{i0S}\}_{i \in \mathcal{O}_{FS}}$ and the vector of Home unit costs is $\mathbf{c}_{0HS} = \{c_{i0S}\}_{i \in \mathcal{O}_{HS}}$. Trade is

[28] The interdependence between decisions of exporting and product differentiation arises if there are economies of scale to producing the same variety for the domestic and foreign markets. Then trade, by expanding the opportunities to export less-differentiated varieties, may decrease the incentives for firms to differentiate. Also in foreign direct investment, the decision of servicing a foreign market through exports or a foreign affiliate may be influenced by the affiliate's ability to couple the firm's products with non-tradable services. While interesting, these cases are beyond the scope of this paper.

balanced if Home exports to Foreign equals its imports from Foreign:

$$
\begin{aligned}
&Y^* w^{1-\sigma} \int_0^1 \sum_{\{i \in S: \tilde{c}_{i0S} \leq c^*(w)\}} (\tilde{c}_{i0S})^{1-\sigma} dS \\
&= y \overline{P}^{\eta-1} \int_0^1 \left[[P_{F0}(\mathbf{c}_{0FS}, \mathbf{c}_{0HS})]^{1-\sigma} [P_0(\mathbf{c}_{0S})]^{\sigma-\eta} + \sum_{i \in \mathcal{D}_{FS}} \left(\frac{\eta c_{iDS}}{\eta - 1} \right)^{1-\eta} \right] dS. \qquad (12)
\end{aligned}
$$

The general equilibrium is a set of strategies, one for each firm, and a vector $(w, \overline{P}, y)$ such that firm strategies are subgame perfect equilibrium strategies in all sectors, and equations (10), (11) and (12) hold.[29]

4.2 Market Inefficiencies and Trade

We find conditions for trade to increase differentiation in general equilibrium, and evaluate whether such differentiation improves welfare. We start by showing market inefficiencies in the allocation of labor and in discrete choices. Throughout, denote the markup of firm $i \in \mathcal{O}_S$ with μ_{i0S} and the markup of $i \in \mathcal{D}_S$ as $\mu_D = \eta/(\eta - 1)$. These markups are the equilibrium markups for all subgames after discrete choices are made, not just for the subgame perfect equilibrium path. Markup μ_{i0S}, implicitly defined in (7), depends on the vector of all unit costs in $\mathcal{O}_S$ but we omit its argument for ease of notation.

Lemma 5 ***Labor misallocation.*** *Consider any set of discrete choices with the corresponding profit-maximizing prices and market-clearing quantities. A planner can reallocate labor used for domestic production but cannot change discrete choices or the quantities imported and exported. For any two firms in the same nest, the planner allocates relatively more labor to the more productive firm compared to the market. The planner also allocates more labor to differentiated varieties relative to less-differentiated varieties.*

As in the literature, markup dispersion leads to labor missallocation. The proof in Appendix D is a small extension of Edmond et al. (2015). To see it, consider two less-differentiated varieties $i, i' \in S$ with labor requirements $\tilde{c}_{i0S} < \tilde{c}_{i'0S}$ and hence markups $\mu_{0iS} > \mu_{0i'S}$. Standard CES maximization implies the following relationship between the

[29] Although the subgame perfect equilibrium is unique in all sectors for any $(w, \overline{P}, y)$, multiple general equilibria may exist because spending on foreign varieties may not be increasing in domestic wages everywhere. For some parameter values, a decrease in w may increase product differentiation and decrease domestic sales by Home firms. The results below are phrased to hold in cases with multiple equilibria.

planner's and the market's labor allocations:

$$\frac{\text{labor}_i^{\text{planner}}}{\text{labor}_{i'}^{\text{planner}}} = \left(\frac{\tilde{c}_{i0S}}{\tilde{c}_{i'0S}}\right)^{-\sigma} > \left(\frac{\tilde{c}_{i0S}/\mu_{0iS}}{\tilde{c}_{i'0S}/\mu_{0i'S}}\right)^{-\sigma} = \frac{\text{labor}_i^{\text{market}}}{\text{labor}_{i'}^{\text{market}}}.$$

The consumer chooses quantities based on prices, and the planner does it based on costs. Then, the consumer spends relatively less on varieties with higher markups, the differentiated varieties and the more productive varieties within the less-differentiated nest as stated in Lemma 5.

We now turn to discrete choices. Fix a sector and consider a subgame after all of discrete choices are made. Prices and quantities are set by the market equilibrium. A planner can change a single firm's discrete choice, and the market again sets prices and quantities to the new subgame equilibrium. We compare the marginal social gain from this change in discrete choice to the firm's private gain.

Such a comparison involves reallocating labor from the variety to the rest of the economy. Once fixed costs are incurred, the economy exhibits constant returns to scale. Then, the marginal cost of labor is $C = wL/Q$ where Q is the standard aggregate quantity under nested CES preferences, $Q = y/\overline{P}$, and L is labor allocated for production[30]

$$L = 1 - \int_0^1 \left(\left|\mathcal{O}_{HS}\right| \tilde{f}_0 + \left|\mathcal{D}_{HS}\right| \tilde{f}_D + \left|\{i \in S_H : \tilde{c}_{i0S} \leq c^*(w)\}\right| f^* \right) dS$$

where $\left|\cdot\right|$ denotes the number of elements in a set. Define the average markup as $\overline{\mu} = \overline{P}/C$, price over marginal cost. By Roy's identity, the valuation of a differentiated variety $i \in S$ for a planner who cannot determine prices and quantities is:

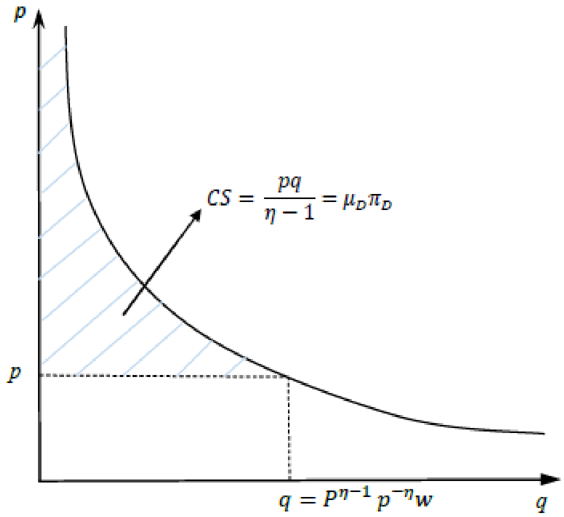
$$u_D(c_{iDS}) = \overline{P}^{-1} \underbrace{\int_{\mu_D c_{iDS}}^{\infty} q_D(p')dp'}_{\text{consumer surplus}} - C^{-1} f_D \tag{13}$$

where $\overline{P}^{-1}$ is the marginal utility of income, $\mu_D c_{iDS}$ is the firm's equilibrium price, and

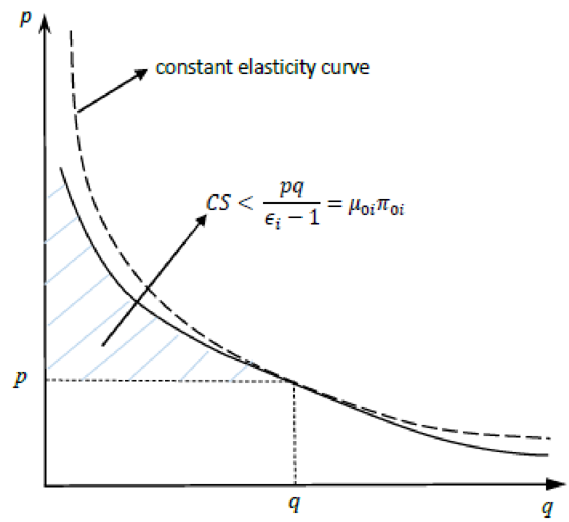
[30] Aggregate quantity is:

$$Q = \left[\int_{\mathcal{N}} Q_n^{(\eta-1)/\eta} dn\right]^{\eta/(\eta-1)}$$
$$\text{where} \quad Q_n = \left[\sum_{i \in n} q_i^{(\sigma-1)/\sigma}\right]^{\frac{\sigma}{\sigma-1}}$$

The expression $C = L/Q$ holds also in an open economy because, net of fixed costs, international trade is effectively a constant returns to scale technology that transforms domestic goods into imports.



(a) Differentiated Variety



(b) Less-Differentiated Variety

Figure 3: Consumer surplus terms (CS) in equations (13) and (16)

$q_D(p') = \overline{P}^{\eta-1}(p')^{-\eta}$ is the quantity demanded from a differentiated firm with price p' in equation (3). Figure 3(a) illustrates the consumer-surplus term. Since $q_D(p')$ has a constant elasticity the consumer surplus term has closed form solution, $\mu_D \pi_D(c_{iDS})$. Substituting it in (13), we have

$$\begin{aligned} u_D(c_{iDS}) &= \overline{P}^{-1} \mu_D \pi_D(c_{iDS}) - C^{-1} f_D \quad (14) \\ &= C^{-1} \left[\left(\frac{\mu_D}{\overline{\mu}} \right) \pi_D(c_{iDS}) - f_D \right] \\ &> C^{-1} [\pi_D(c_{iDS}) - f_D] \quad (15) \end{aligned}$$

where the inequality holds because $\mu_D > \overline{\mu}$.[31] The term in brackets is firm i's private profit from producing a differentiated variety.

For a less-differentiated domestic variety, define $q_0(\mathbf{p}_{-i0S}, p')$ as the quantity demanded of variety i when its price is p' and all its competitors' prices are at their subgame equilibrium level, vector $\mathbf{p}_{-i0S}$, with elements $p_{i'0S}$. From equation (3),

$$q_0(\mathbf{p}_{-i0S}, p') = \overline{P}^{\eta-1} \left((p')^{1-\sigma} + \sum_{i' \in \mathcal{O}_S, i' \neq i} (p_{i'0S})^{1-\sigma} \right)^{\frac{\sigma-\eta}{1-\sigma}} (p')^{-\sigma}$$

Since vector $\mathbf{p}_{-i0S}$ is a function of the vector of costs $(\mathbf{c}_{-i0S}, c_{i0S})$ the marginal contribution

[31] The inequality holds strictly because the markup from exporting is $\sigma/(\sigma-1)$. If the markup from exporting were μ_D, then a non-zero mass of firms sharing a nest would also imply $\mu_D > \overline{\mu}$.

of firm i to welfare is also a function of these costs. It satisfies

$$u_0(\mathbf{c}_{-i0S}, c_{i0S}) < \overline{P}^{-1} \underbrace{\int_{\mu_{i0S}c_{i0S}}^{\infty} q_0(\mathbf{p}_{-i0S}, p')}_{\text{consumer surplus}} - C^{-1} f_0 \tag{16}$$

$$< \overline{P}^{-1} \mu_{i0S} \pi_0(\mathbf{c}_{-i0S}, c_{i0S}) - C^{-1} f_0 \qquad \text{for all } \mu_{i0S} < \mu_D \tag{17}$$

$$< C^{-1}(\pi_0(\mathbf{c}_{-i0S}, c_{i0S}) - f_0) \qquad \text{if } \mu_{i0S} < \overline{\mu} \tag{18}$$

The first inequality holds because the variety does not have a monopoly in nest $\mathcal{O}_S$ by assumption (at least one foreign firm is in $\mathcal{O}_S$). When the variety is taken out of the market, the consumer's valuation of other varieties in $\mathcal{O}_S$ increases.[32] The second inequality is illustrated in Figure 3(b). The dashed line illustrates the hypothetical demand curve $\tilde{q}_i(p) = Ap^{-\epsilon}$ where ϵ is the elasticity of demand of the firm (defined in equation (7)) and constant A is defined by the intersection point, $\tilde{q}_i(\mu_{i0S}c_{i0S}) = q_0(\mathbf{p}_{-i0S}, \mu_{i0S}c_{i0S})$. The consumer surplus term if demand were $\tilde{q}_i(p)$ would be

$$\int_{\mu_{i0S}c_{i0S}}^{\infty} Ap^{-\epsilon} dp = \frac{A(\mu_{i0S}c_{i0S})^{-\epsilon+1}}{\epsilon - 1} = \frac{\mu_{i0S}c_{i0S}[q_0(\mathbf{p}_{-i0S}, \mu_{i0S}c_{i0S})]}{\epsilon - 1} = \mu_{i0S}\pi_0(\mathbf{c}_{-i0S}, c_{i0S})$$

The shaded area in the figure is strictly less than the area implied by this constant elasticity function, because the elasticity of demand is higher than ϵ for all prices higher than the equilibrium price. The terms in parenthesis in (15) and (18) are the firm's private net profits under differentiation and less-differentiation, resepcively. Together, inequalities (15), (17) and (18) imply:

Lemma 6 *Consider the marginal social benefit of changing a firm's discrete choice when the planner cannot set prices and quantities after discrete choices are made. The marginal social benefit of a differentiated variety is always greater than the private gain, whether the comparison is to exiting or to producing a less-differentiated variety. The marginal social benefit of a less-differentiated variety is smaller than the private profit if the firm is sufficiently less productive than its competitors so that* $\mu_{0i} < \overline{\mu}$.

In partial equilibrium Proposition 3, a sufficiently large decrease in foreign costs increases the gain from differentiation for surviving firms. In general equilibrium, the conditions for this result are more stringent because the decrease in the overall price index $\overline{P}$ discourages differentiation if differentiation requires an investment, $f_D > f_0$.

[32] The demand and price of these other varieties increase. So, by Roy's identity, their valuation increases.

Proposition 7 *A sufficiently large decrease in foreign costs in a share* $\alpha \in (0,1)$ *of sectors increases exit from the domestic market of firms in all sectors. Among surviving firms, it increases product differentiation if* $f_D \leq f_0$*. Welfare after the shock is higher than in the equilibrium of an alternative subgame in which these surviving firms do not differentiate their products and other firms maintain their discrete choices.*

Appendix C2 proves that, even when the shock is not enough to drive out all Home firms from the domestic market, a sufficiently large decrease in foreign costs in a non-zero mass of sectors decreases the overall price index $\overline{P}/w$ and P_{-i0}/w in the sectors directly affected by the shock. Then, operating profits π_D and π_0 from domestic sales in (6) both decrease. The ratio of profits is

$$\frac{\pi_D}{\pi_0} = \frac{\epsilon_{i0S}}{\eta} \left(\frac{P_{0S}}{w} \right)^{\eta-\sigma} \left(\frac{\epsilon_{i0S}\tilde{c}_{i0S}}{\epsilon_{i0S}-1} \right)^{\sigma-1} \left(\frac{\eta \tilde{c}_{iDS}}{\eta - 1} \right)^{1-\eta}$$

where we have omitted the arguments of functions π and P_{0S}, and ϵ_{i0S} is the firm's endogenous elasticity of demand if it is less-differentiated. The ratio π_D/π_0 changes with the shock only through the cost of firm i's competitors relative to wages, P_{-i0}/w. Then, the shock increases π_D/π_0. The net gain from product differentiation is $\pi_D - \pi_0 - w(f_D - f_0)$. The increase in the ratio π_D/π_0 increases this gain. The decrease in levels π_D and π_0 decreases the gain if $f_0 < f_D$, increases it if $f_0 > f_D$ and has no effect if $f_0 = f_D$.

For the welfare claim, consider the set of firms that change from producing a less differentiated variety in $\mathcal{O}_S$ to producing a differentiated variety in $\mathcal{D}_S$ in a non-zero mass of sectors S.[33] From Lemma 6, the social planner benefits from moving these firms from $\mathcal{D}_S$ back to $\mathcal{O}_S$ after the trade shock only if general equilibrium effects increase the profitability of less-differentiated varieties. Appendix C.2 shows that this is only possible if Home's terms of trade decrease (a welfare loss) and labor moves from differentiated varieties to less-differentiated varieties, which reduces welfare by Lemma 5.

Table 4 suggests the empirical relevance of the condition $f_D \leq f_0$. In sectors that experienced disproportionately large tariff cuts, firms all sizes, small and large, introduced new goods and switched to more skill intensive sectors. The model can only rationalize increases in product differentiation among small firms if such differentiation does not require large fixed costs, i.e., $f_D - f_0 \approx 0$. Then, by Proposition 7, import competition

[33] We rule out the possibility that other firms respond optimally to more firms entering the less-differentiated nest because the social planner may value differentiation of various varieties in a different ordering than the strategic game played by the market. So, shifting a variety from differentiation to nest $\mathcal{O}_S$ may increase welfare if it leads another firm to differentiate or exit nest $\mathcal{O}$, partially correcting for another market distortion.

increases product differentiation in the general equilibrium model. The welfare gains from trade are higher with the differentiation option than in a scenario where firms cannot differentiate their products, as in standard models.

A back of the envelope calculation suggests that these new gains from trade may be sizable. The coefficient on column (2) of Table 2 indicates that a one standard deviation reduction in log output tariffs (around .5) is associated with an increase in new products of 0.8 percentage points in total sales (multiplied by -0.0157). If we set $\eta = 2$ and $\sigma = 10$ the welfare gain from increasing the number of new differentiated products by 0.008 and decreasing more substitutable products by the same share increases welfare by 0.7 percent, a significant value relative to standard calculations of the welfare gains from trade.[34]

5 Extension of the Model: Input Suppliers

We add inputs to the model to interpret the empirical results on the indirect effects of tariff cuts on import-competing firms' input suppliers. The exercise further highlights the differences between measured productivity and non-pecuniary firm outcomes, discussed in Section 3.2. Since the focus is on positive predictions, we return to the partial equilibrium model of Section 3 and omit all sector subscripts. The general equilibrium results remain if the sector of material inputs modelled is sufficiently small, say relative to labor and capital, to affect downstream costs.

We assume that less-differentiated upstream firms sell only to less-differentiated downstream firms. This assumption is made for simplicity, and Appendix E.1 proves the results under the weaker assumption that less-differentiated downstream firms use intensively less-differentiated inputs, relative to differentiated downstream firms. If product differentiation involves broad quality upgrades, this assumption is justified with ample evidence from the literature that higher-quality firms use intensively higher-quality inputs.[35] Take again the auto-maker Chery. Its increase in product scope was viable through just-in-time inventory controls and investments in modern equipment, which produces higher-quality parts in small batches. Quality improvements were in Chery's own interest given its new commitment to make replacement parts available. To be effective, all these improve-

[34]Using the definition of $\overline{P}$ in (3), the estimated decrease in price is $\hat{\overline{P}} \approx 1.008^{1/(1-\eta)} * 0.992^{1/(1-\sigma)}$. The value $\eta = 2$ is between Edmond et al. (2015)'s estimate $\eta = 1.28$ and Broda and Weinstein (2006)'s median elasticity of 5-digit SITC codes, estimated to 2.7. To get a sense magnitude for the standard gain from trade, assume absorption as 50% larger than GDP and the elasticity of trade with respect to trade costs to be 5. Imports as a share of GDP increased from 14% to 28% in the period of our data, then the welfare gain in Arkolakis et al. (2012) is $(0.81/0.91)^{-1/5} - 1 = 2.2$ percent.

[35]See Schott (2004) and Verhoogen (2008) for skill intensity, and Kugler and Verhoogen (2011), Manova and Zhang (2012), and Fieler et al. (2018) for labor and material input usage.

ments in Chery—production in small batches, higher-quality parts, and efficient inventory controls—have to be matched by mirror improvements in its input suppliers.

5.1 Set up with input suppliers

We present the set up here and the results in Section 5.2. The downstream sector is modelled exactly as in Section 3, and the upstream sector (input suppliers) is modelled symmetrically. We use subscript U to distinguish upstream variables from the downstream variables above. There is an exogenous finite set of potentially active downstream firms and upstream firms. A strict subset of these firms are foreign. Foreign firms have exogenous unit costs and do not make discrete choices. They have pre-assigned nests and at least one downstream foreign firm is in the less-differentiated downstream nest $\mathcal{O}$.

Each input supplier has monopoly rights over a unique input variety. It chooses to exit, produce a less-differentiated variety, or produce a differentiated variety. If it produces, it chooses its price. To focus on import competition, we assume that the upstream firms modelled do not export or that their decision to export is independent from their decision to differentiate their products. If the upstream firm i produces a less-differentiated variety, it pays a fixed cost f_{0U} and an additional cost c_{i0U} for each unit produced. If it produces a differentiated variety, its fixed cost is f_{DU} and unit cost is c_{iDU}.

Less-differentiated firms. Less-differentiated upstream firms only sell inputs for the variable production costs of less-differentiated downstream firms.[36] The unit cost of a domestic, less-differentiated downstream firm $i \in \mathcal{O}$ is $c_{i0} = \overline{c}_0/\phi_{i0}$ where ϕ_{i0} is a firm-specific productivity parameter and $\overline{c}_0$ is the cost of a bundle of inputs, common to all less-differentiated downstream varieties. Let

$$\overline{c}_0 = \left[\int_{\mathcal{N}_U} P_{n_U}^{1-\eta_U} dn_U\right]^{\frac{1}{1-\eta_U}} \tag{19}$$

$$\text{where} \quad P_{n_U} = \left[\sum_{i \in n_U} (p_i)^{1-\sigma_U}\right]^{\frac{1}{1-\sigma_U}}, \tag{20}$$

and p_i is the price of variety i, n_U is a nest of inputs, and $\mathcal{N}_U$ is the exogenous set of these nests, which may include labor, capital, and materials from other sectors. Let $\mathcal{O}_U$ be the endogenous set of less-differentiated upstream varieties, and P_{0U} be its price index defined in (20). Since there is a continuum of nests $\mathcal{N}_U$, equilibrium P_{0U} does not affect

[36] The proof of proposition 8 holds almost unchanged if inputs are also used in fixed costs. Only the expression for X_{0U} in (24) changes.

$\bar{c}_0$. Appendix E.2 studies the model where upstream firms are sufficiently large to affect $\bar{c}_0$.[37] Assume $\sigma_U > \eta_U > 1$.

A less-differentiated upstream firm with unit cost c chooses price p to maximize operating profit

$$\max_p X_{0U} c_0^{\eta_U - 1} (P_{0U})^{\sigma_U - \eta_U} p^{-\sigma_U} (p - c) \tag{21}$$

where X_{0U} is the equilibrium total spending on less-differentiated materials by domestic downstream firms (below).

Analogous to the downstream pricing equation (7), the optimal markup of the upstream firm is $\epsilon_U/(\epsilon_U - 1)$ where the endogenous elasticity of demand is a weighted average between the within-nest elasticity σ_U and the across-nest elasticity η_U:

$$\epsilon_U = \sigma_U(1 - s_U) + \eta_U s_U \tag{22}$$

and $s_U = (p/P_{0U})^{1-\sigma}$ is the market share of the firm in nest $\mathcal{O}_U$. Equation (22) implicitly defines prices in nest $\mathcal{O}_U$ given a vector of costs $\mathbf{c}_{0U}$. Following the notation in the downstream sector, we write $\epsilon_{0U}(\mathbf{c}_{-i0U}, c_{i0U})$ as the elasticity of demand of an upstream firm with unit cost c_{i0U} facing competitors with units costs vector $\mathbf{c}_{-i0U}$, and $P_{0U}(\mathbf{c}_{0U})$ as the equilibrium price index, with $\mathbf{c}_{0U} = \{c_{i0U}\}_{i \in \mathcal{O}_U}$. Firm i's operating profit is

$$\pi_{0U}(\mathbf{c}_{-i0U}, c_{i0U}, X_{0U}) = X_{0U} \bar{c}_0^{\eta_U - 1} \frac{[P_{0U}(\mathbf{c}_{0U})]^{\sigma_U - \eta_U}}{\epsilon_{0U}(\mathbf{c}_{-i0U}, c_{i0U})} \left(\frac{[\epsilon_{0U}(\mathbf{c}_{-i0U}, c_{i0U})] c_{i0U}}{\epsilon_{0U}(\mathbf{c}_{-i0U}, c_{i0U}) - 1} \right)^{1-\sigma_U} \tag{23}$$

From (7) and (8), spending on variable inputs by less-differentiated downstream firms is

$$X_{0U}(\mathbf{c}_{0F}, \mathbf{c}_{0H}) = y \overline{P}^{\eta - 1} [P_0(\mathbf{c}_0)]^{\sigma - \eta} \sum_{i \in \mathcal{O}_H} \left(\frac{\epsilon_0(\mathbf{c}_{-i0}, c_{i0})}{\epsilon_0(\mathbf{c}_{-i0}, c_{i0}) - 1} \right)^{-\sigma} (c_{i0})^{1-\sigma} \tag{24}$$

The vector of Home and Foreign unit costs $\mathbf{c}_{H0} = \{c_{i0}\}_{i \in \mathcal{O}_H}$ and $\mathbf{c}_{F0} = \{c_{i0}\}_{i \in \mathcal{O}_F}$ enter differently because Foreign firms selling domestically do not buy inputs locally.

Differentiated firms. Like in the downstream sector, the price and profit of a differentiated variety are exogenous. A differentiated input supplier with unit cost c charges

[37] Pricing decisions of upstream firms change because they internalize the effect of their prices on $\bar{c}_0$, and on prices, sales and spending on materials by downstream firms. The main conclusions below hold, except that less-differentiated upstream firms may decrease their markups in response to import competition downstream. This effect, however, is small if the ratio of the upstream firm sales to the total cost of domestic less-differentiated downstream firms is small. See Appendix E.2 for a precise expression.

markup $\frac{\eta_U}{\eta_U - 1}$ over marginal cost and gets profits

$$\pi_{DU}(c) = c^{1-\eta_U} Y_{DU}. \tag{25}$$

Parameter Y_{DU} captures the size and tightness of the market, input costs, and potential efficiency changes from product differentiation. Input costs of differentiated downstream firms c_{iD} are also exogenous.

Equilibrium with input suppliers. There is an exogenous finite set of domestic and foreign upstream and downstream firms. Foreign firms do not make discrete choices. At least one downstream foreign firm is less-differentiated. The cost of all varieties is exogenous and known. Timing is as follows. (i) In ascending order of costs c_{i0U}, all domestic upstream firms make their discrete choices. (ii) In ascending order of costs c_{i0}, all domestic downstream firms make their discrete choices. (iii) All firms, upstream and downstream, domestic and foreign, simultaneously set prices. (iv) Markets clear.

Discrete choices are set before prices so that firms cannot commit on prices to manipulate discrete choices. The ordering of (i) and (ii) is not important. The simultaneous setting of prices implies that a firm best responds to other firms' equilibrium prices, and that the pricing decisions above are correctly specified. The actions of a finite set of upstream firms in one input nest, out of a continuum, do not change c_{i0} or c_{iD}. Hence, the subgame perfect equilibrium in Section 3 is unchanged. But the sales and the discrete choices of downstream firms affects the profits of upstream less-differentiated firms through spending on materials X_{0U} in (24).

5.2 Characteristics of the Equilibrium with Input Suppliers

The game among upstream firms is solved by backward induction as in Section 3. A vector of all firms' discrete choices determine the sets of exiting, less-differentiated and differentiated varieties, upstream and downstream. The corresponding payoffs are the operating profits in (8), (23), and (25) minus fixed costs. Starting with the least productive downstream firm, each firm effectively chooses among subgames when choosing whether to exit, produce a less-differentiated variety or a differentiated variety. For the same reason as before, the subgame perfect equilibrium is unique up to a perturbation of parameters.

As in Proposition 1, the first mover advantage of more productive firms implies that there exist exit cutoffs, $\tilde{c}$ and $\tilde{c}_U$ for downstream and upstream firms, as long as their productivity can be ranked ($c_{i0} < c_{i'0}$ if and only if $c_{iD} < c_{i'D}$, and $c_{i0U} < c_{i'0U}$ if and only if $c_{iDU} < c_{i'DU}$). Proposition 8 states how the subgame perfect equilibrium changes when the costs of downstream foreign firms decrease sufficiently. It focuses on upstream firms only because the effect of the shock on downstream firms in Proposition 3 is unchanged.

Proposition 8 ***Upstream Firms and Import Competition Downstream*** *A sufficiently large decrease in the cost of downstream foreign firms increases the exit of upstream firms. Among surviving upstream firms, it increases product differentiation and markups.*

Proof By Proposition 3, a sufficiently large decrease in downstream foreign costs strictly decreases the sales of downstream firms that remain less differentiated, and it decreases the set of less-differentiated downstream firms, through exit or product differentiation. As a result, the absorption of less-differentiated material inputs X_{0U} decreases. As foreign costs go to zero, X_{0U} also goes to zero, so that π_{0U} decreases for all less-differentiated upstream firms even if the firm becomes a monopolist in set $\mathcal{O}_U$. Then, *ex ante* less-differentiated upstream firms exit or differentiate their products. Their prices in (22) are affected by the shock only if the set of less-differentiated input suppliers change. Since we have just proved that a sufficiently large decrease in downstream foreign costs shrinks set $\mathcal{O}_U$, it increases markups of upstream firms that remain less-differentiated. ∎

The effect of import competition downstream in increasing exit and product differentiation is the same for import-competing firms and their input providers. But the effect on the markups of less-differentiated firms is the opposite. Market shares determine the markups in the model. While import competition decreases the market share of import-competing downstream firms, it does not directly change the market share of upstream firms. Less-differentiated input suppliers increase their markups if other *ex ante* less-differentiated input suppliers exit or differentiate.

This difference arises because, for a downstream firm, product differentiation consists of finding a market niche where it can insulate itself from import-competition, while for an upstream firm, differentiation changes the firm's customers due to the assumption that differentiated downstream production is intensive in differentiated inputs.

We use Proposition 8 to interpret the coefficients on downstream tariffs in our empirical specification (1), which capture the effect of tariff cuts on the input suppliers of import-competing firms. Tables 2 and 3 suggest that, in response to tariff cuts downstream, these input suppliers introduce new goods and switch to skill-intensive sectors, in line with increases in product differentiation in the model. In all specifications, either the coefficient on downstream tariffs is smaller (in magnitude) and less statistically significant than the coefficient on output tariffs, or equality cannot be rejected. This result suggests plausibly that the indirect effect of tariff cuts on input suppliers is smaller than the direct effect on import-competing firms.

In contrast, when the dependent variable is TFP in Table 1, the coefficient on downstream tariffs is about seven times larger than the coefficient on output tariffs in all IV specifications. This result is in line with the movement in markups predicted by Proposition 8 and reinforces our earlier caution on interpreting TFP changes during trade liberalizations (Section 3.2).

6 Robustness and Extensions of Empirical Results

We focus on robustness and extensions of the empirical results. References to the theoretical appendices appear in Sections 3 through 5. Appendix A.2 tests other predictions of the model. Output and downstream tariff reductions increase the probability of exiting (Table A.8) and of switching four-digit sectors (Table A.9). The latter result is indicative that the firm changes its output in response to tariff cuts, as predicted by the model.

Appendix A.1 repeats the TFP regression of Table 1 for various specifications. Table A.1 uses lagged tariffs and includes SOE's and multinationals with minority foreign ownership, in a specification close to Brandt et al. (2017).[38] Table A.2 drops sector fixed effects. To check if collinearity between tariff measures is driving the results, Table A.3 confirms that the coefficients do not change when we drop one tariff measure at a time from the regressions. To check for selection, Table A.4 repeats the regression using a balanced panel of the firms that are in the sample during all ten years of data. We also follow Wooldridge (2010) in estimating a selection equation using a probit, and then including the estimated Mills ratio in the main specification (Table A.5). In Table A.6, we exclude from the regression data on key sectors like textiles and apparel, and the computer industry. Table A.6 includes tariffs in the first stage of the TFP estimation, and Table A.7 estimates TFP following Ackerberg et al. (2015).

In all IV specifications of Tables A.1 through A.7, the magnitude of the coefficient on downstream tariffs is seven to ten times larger than the coefficient on output tariff. The coefficient on output tariff is generally negative, but it is less robust, in terms of statistical significance in the OLS and IV specifications, than the coefficient on downstream tariffs. These results are consistent with the model where import competition has an ambiguous effect on the revenue productivity of import-competing firms (Proposition 3) and increases the productivity of these firms' input suppliers (Proposition 8).

[38] In principle, our mechanism applies to multinationals operating in China. A difference arises if (i) domestic firms have better information about the Chinese market and an edge at tailoring their goods to domestic tastes, or (ii) if multinational affiliates are oriented towards global production chains and foreign markets and are not as affected by import-competition in China.

In the TFP regressions of Table 4, the coefficient on output tariffs increases systematically with quartile of firm sales. The coefficient on the largest quartile is positive, and the coefficient on the smallest quartile is negative, and the difference is statistically significant. Appendix Table A.8 repeats the regression of Table 4 (i) including SOE's and multinationals (ii) with only a balanced panel of firms, (iii) with TFP measured à la Ackerberg et al. (2015), (iv) excluding textiles and apparel, and (v) excluding computers and peripherals. Table A.8 presents the results for all firms and for non-exporters separately, for OLS and IV regressions, and where applicable, for estimating the TFP regression (2) with the Olley-Pakes method or with OLS. The results in Table 4 hold in all these specifications.

Tables 2 and 3 associate tariff cuts to the introduction of new goods and to switches to more skill intensive sectors. Appendix Tables A.9 though A.12 modify the regressions in Tables 2 and 3 by (i) including SOE's and multinationals with minority foreign ownership (ii) including only a balanced panel of firms, (iii) excluding textiles and apparel, and (iv) excluding computers and peripherals. Relative to Table 2, the results on the introduction of new goods are weaker when we include SOE's and multinationals (Table A.9A) or when we include only a balanced panel of firms (Table A.9B). Multinationals may be disadvantaged relative to local private firms to tailor their goods to the domestic market or to offer non-tradable services. They may also be more influenced by offshoring opportunities than import competition in China. The results may be weaker with the balanced panel if surviving firms are more likely to have had very successful products and be less prone to introduce new varieties. Reassuringly and in line with these explanations, the coefficients are negative and statistically significant when we restrict the sample to non-exporting firms, the set of firms for which we expect the results to hold more strongly.

Tables A.11 and A.12 confirm the finding in Table 3 that tariff cuts shift firms toward skill-intensive sectors in China, an unskill-abundant country. In all specifications, the coefficients on output tariffs are negative and statistically significant, and they have roughly the same magnitude as the coefficients in Table 3. In the IV regressions, the coefficients on downstream tariffs are also negative, suggesting that input providers also shift to more skill-intensive sectors in response to tariff cuts.

In sum, the Appendix confirms that, in response to tariff cuts, non-exporting domestic firms introduce new products and shift toward skill-intensive sectors, consistent with firms in the model escaping import competition through product differentiation. The productivity regressions confirm that, when import competition tightens, the revenue productivity of small firms increase relative to large firms, and that the revenue productivity of import-competing firms' input suppliers increase. These movements in measured productivity are consistent with the model's predictions for markups.

7 Conclusion

We set out to narrow the gap between the academic literature and the prevailing view among policy makers and economists that tariff cuts are good for the performance of import-competing firms. We develop a simple extension of Atkeson and Burstein (2008), where import-competing firms may differentiate their products to escape foreign competition. In practice, firms may offer customized products, cater to domestic tastes, or complement their products with non-tradable services. Since the increase in product differentiation spurred by import competition improves welfare in the model, it provides a rationale for policy makers' view above.

Using data on Chinese firms during China's accession to the WTO, we provide evidence that import-competing firms respond to tariff cuts by introducing new goods, and switching to skill-intensive sectors. These findings suggest that import-competition encourages product innovation, in line with the model and policy makers' view. The ambiguous effect of import-competition on the markup of domestic firms in the model may explain the mixed evidence in the literature relating tariff cuts to firm productivity. Through variable markups, the model also explains more subtle effects of tariff cuts on the revenue productivity of heterogeneous firms and input suppliers. Revenue productivity, the standard measure of firm performance in the empirical literature, is a poor measure of product differentiation because it confounds the positive effects of import competition on innovation with negative pro-competitive effects on markups. We circumvent this difficulty using data on non-pecuniary firm outcomes which are comparable across time even in periods of large changes in demand, technologies and output, such as trade liberalization episodes.

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