Escaping Import Competition in China

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Abstract

We use establishment data from China spanning its WTO accession in 2001. Tariff cuts are associated with increases in revenue productivity, the introduction of new goods, switches to skill-intensive sectors. We propose a model in which 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 profit from differentiation is an inverted U-shaped function of firm productivity, and it increases with import competition. Differentiation explains product innovation in the data, and markups explain why the increase in revenue productivity is larger for small firms. A firm's profit from differentiation is smaller than the social welfare gain. So, differentiation may constitute a new source of gain from trade.

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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.

We study the effects of import competition on Chinese manufacturing firms using panel data from 1998 to 2007, spanning China's accession to the WTO in 2001. Within firms, tariff cuts are associated with increases in revenue productivity, the introduction of new goods, and switches to more skill-intensive sectors.[2] These findings are at odds with standard 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.[3]

We propose that domestic firms respond to import competition by seeking market niches that are insulated from foreign competition. They cater to domestic tastes, offer greater customization, and bundle products with non-tradable services. For example, 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. Chery Automobiles introduced several new, small car models with many optional features, and it made replacement parts readily available. These changes insulate Chery from import

[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 Chen and Steinwender (2019). Our empirical findings do not preclude the presence of x-inefficiencies, but our mechanism has more specific predictions that are born out by the data.

[2]To mitigate the problem of endogeneity, 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.

[3]See references in Section 2.3.

competition, not only because small and fuel-efficient cars appeal to Chinese consumers, but also because it is difficult for firms producing cars abroad to offer customized accoutrements and a wide range of replacement parts.[4] To implement this strategy, Chery invested in research and development, and in skill-intensive technologies such as modern machinery amenable to production in small batches, and integrated computer systems that enable just-in-time inventory controls.

In line with the empirical findings, this sort of reaction to foreign competition involves the introduction of new goods. While many of the switches to skill-intensive tasks occur within sectors, some may imply a switch in the firm's four-digit sectoral classification. Common sector switches in the data include from cotton and chemical fibers to textile and garment manufacturing, and from steel rolling processing to metal structures. They suggest upgrading to higher value-added sectors with a greater scope for differentiation. Markup responses may explain changes in revenue productivity, a measure of the ratio of revenue to cost. Import competition decreases the markup of firms that remain in direct competition with foreigners, but may increase the markup of firms that escape competition.

We formalize these points in a model with heterogeneous firms and a demand system with nested constant elasticity of substitution (CES). In decreasing order of productivity, each firm chooses whether (1) to exit, (2) to produce a variety in a nest with other competitors, or (3) to incur a higher (fixed or variable) cost and produce in a new nest where it is a monopolist. After these discrete choices are made, all firms simultaneously set prices. The choice of product differentiation, between (2) and (3), is our only departure from Atkeson and Burstein (2008).

A firm that differentiates its product faces a lower elasticity of demand and sells more for a given price. The incremental profit from differentiation is a non-monotonic function

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

of the firm's productivity, given the productivity of other firms in the common nest. If the firm is very unproductive, its profit is small in any nest. If the firm is much more productive than its competitors, then it will hold near monopoly power and charge a high markup even in the common nest. The benefit from further differentiation is small.

We study how the subgame perfect equilibrium changes with a shock to foreign competition in a single sector. We assume that a large reduction in foreign costs disproportionately tightens competition in the common nest. It then increases the profit from product differentiation for domestic firms. The markup increases for firms that escape competition and decreases for firms that remain in the common nest. When firms of all sizes respond to the shock similarly in terms of product differentiation, the markup of small firms increases relative to large firms. Small firms' prices are closer to cost. They have a more limited scope than large firms to decrease their markups in response to tighter competition in the common nest, but they increase their markups more if they differentiate and become monopolists in a nest.[5]

The increased differentiation among domestic firms is consistent with the link between tariff cuts and the introduction of new products and switches to skill intensive sectors. This link is of similar magnitude for small and large firms in the data, suggesting through the lenses of the model that large and small firms differentiate their products to a similar extent when import competition tightens. The model then predicts that the markup of small firms increases relative to large firms, and we find some evidence for this pattern in the data on revenue productivity.[6]

We find conditions for a reduction in foreign costs that affects a large share of sectors to increase differentiation. In the model, the private profit from product differentiation is smaller than the social benefit. Allowing firms to differentiate their products increases the welfare gain from the trade shock relative to a model where firms cannot change their

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

[6]Chen and Steinwender (2019) find a similar heterogeneous effect of competition on productivity.

variety, as in standard settings. A back-of-the-envelope calculation in Section 5 shows that such gain may be sizable.

As stated earlier, revenue productivity is not a good proxy for differentiation in the model because it confounds the positive effect of product differentiation with the negative effect of competition on the markups of import-competing firms in the common nest.[7] To reinforce this point, we extend the analysis to the input suppliers of import-competing firms. Trade unambiguously increases the markup of these firms in the model, and in the data, tariff cuts are associated with larger increases in the productivity input suppliers than that of import-competing firms, directly hit with the shock.[8]

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 markups (their focus is firm size). 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. In Aghion et al. (2005) and Aghion et al. (2015), competition may increase innovation, and the profit from innovation is non-monotonic in productivity. In these models, goods are homogeneous within sectors, and only the most productive firm produces. We bring their results closer to recent quantitative models of international trade with co-existing differentiated varieties. Our welfare analysis complements Spence (1976a), Spence (1976b), Dixit and Stiglitz (1977) and Dhingra and Morrow (2018). Our approach differs from the latter two papers, whose methods apply to monopolistic competition.

The empirical analysis is in Section 2. To highlight the main mechanisms, we present the model of a closed economy in Section 3 and the model of a small open economy in Section 4. The welfare analysis is in Section 5. Section 7 presents extensions and robustness of the empirical results. Section 8 concludes.

[7] See Section 4.3 for references and further discussion on measured productivity.

[8] Domestic input linkages propagate the direct effects of international trade also in Kee and Tang (2016), Fieler et al. (2018), Linarello (2018), and Tintelnot et al. (2018). Our empirical approach follows Javorcik (2004) and Blalock and Gertler (2008)'s studies of spillovers in foreign direct investment.

2 Data and Evidence

2.1 Data Sources

We describe the data in Section 2.1, the empirical specification in Section 2.2, and the results in Section 2.3.

We use an annual survey of industrial establishments collected by the Chinese National Bureau of Statistics. The survey comprises all state-owned enterprises (SOEs), regardless of size, and private enterprises with annual sales of more than 5 million yuan. We use a ten-year unbalanced panel from 1998 to 2007. The data contain information on output, fixed assets, total workforce, wage bill, intermediate input costs, foreign investment, revenue from domestic and export sales. Price indices by sector are reported annually in the official publication. For further details on the survey, see Du et al. (2012), Aghion et al. (2015), and Brandt et al. (2017).

The original dataset has 2,226,104 firm-year observations. We keep only firms in manufacturing, the more tradable sector. We drop three sectors with missing price indices and observations with missing data on output, labor, capital, or material inputs. Our main results restrict the sample to firms with zero foreign ownership and with zero or a minority state ownership. The results with multinationals and SOE's are in Section 7. 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.

2.2 Empirical Specification

Our main regression specification is:

$$y_{it} = \beta \ln \text{Tariff}_{j(i,t)t} + \gamma_1 X_{j(i,t)t} + \gamma_2 X_{i,t} + \alpha_i + \alpha_t + \varepsilon \tag{1}$$

where the subscripts refer to firm i, year t, and the sector $j(i,t)$ of firm i at time t, α_i are firm fixed effects, and α_t are time fixed effects. We cluster standard errors by firm and by the firm's initial sector.

Sector-time control variables X_{jt} include the weighted average of tariffs in sectors upstream and downstream from the firm's own sector j, state ownership in sector j, and foreign ownership in sector j and in sectors upstream and downstream from j.[9] Firm-time controls X_{it} are zero-one dummy variables indicating whether firm i in year t received subsidies, whether it received a tax holiday, and whether it paid below median interest rates on loans. Details on these control variables and their coefficients are in Appendix A.1.

The independent variable of interest is the tariff that China imposes on its imports of sector j at time t. We use instrumental variables to mitigate the concern that firms endogenously influence tariffs through lobbying. 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 initial high tariffs. Following the literature, we instrument for tariffs using the value of tariffs for the firm in 1998 interacted with a dummy variable equal to one after China entered the WTO.[10]

The dependent variables y_{it} are firm outcomes often associated with innovation or quality upgrading in the literature: Revenue total factor productivity (TFP), introduction of new goods, and skill intensity.

For TFP, we estimate separately for each 2-digit sector the production function

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

[9] We follow Javorcik (2004) to construct foreign ownership variables. For tariffs upstream from j, we follow Amiti and Konings (2007) and Brandt et al. (2017), and we use an analogous procedure to measure tariffs downstream from j. We use the Chinese Input-Output Table (2002) to construct these variables.

[10] We use the corresponding instrument for other tariff measures in X_{jt} (Appendix A). Similar instruments appear in Goldberg et al. (2009) for India, Amiti and Konings (2007) for Indonesia, and Attanasio et al. (2004) for Colombia. For China, Brandt et al. (2017) follow a similar approach using as instruments tariff rates from the accession agreement, which were mostly fixed by 1999. We cannot use the initial tariffs alone as an instrument because our regressions have firm fixed effects.

where X is 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. Output and cost variables are deflated with the sector-specific price indices.[11] Our estimated $\log TFP_{it}$ is the predicted value of $\log X_{it} - \hat{\alpha}_{Lj(i,t)} \log L_{it} - \hat{\alpha}_{Mj(i,t)} \log M_{it} - \hat{\alpha}_{Kj(i,t)} \log K_{it}$.

We estimate (2) using the standard two-stage procedure in Olley and Pakes (1996), with OLS and time fixed effects, and following Ackerberg et al. (2015) in Section 7. When TFP is the dependent variable in (1), we add sector fixed effects since TFP is not comparable across sectors.

For the introduction of new goods, we use the share of new products in total sales, reported in the survey, and a dummy variable equal to one if firm i introduces a new product in year t and zero otherwise.

Unfortunately, we only observe the composition of the workforce in the 2004 survey. We define skilled workers as those who have completed a senior-high degree, or a three- or four-year college degree.[12] We calculate the share of skilled workers in the total labor force of each sector in 2004 and rank sectors according to these shares. Of the 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. We use for the dependent variable y_{it} in (1) the ranking of sector $j(i,t)$.

2.3 Empirical Results

Basic Results Table 1 presents the coefficient on tariffs from regression (1). The coefficients are all negative, and they are statistically significant in all IV specifications, including the ones in which we restrict the sample to non-exporting establishments.[13]

[11] Output value 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 using the Chinese input-output table. 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.

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

[13] A possible explanation for the IV results is that firms responded to the large tariff cuts of the WTO accession, but not to smaller tariff cuts in other years.

Table 1: Regressions of Productivity, New Goods, and Sectoral Skill Intensity on Tariffs

dependent variable ↓	coefficient on tariffs	standard error		sample[1]	number of observations	First stage F statistic
Panel A						
Revenue TFP, Olley-Pakes	-0.0304***	0.0027	OLS	all	1,037,738	-
Revenue TFP, Olley-Pakes	-0.0505***	0.0169	IV	all	1,037,738	278
Revenue TFP, Olley-Pakes	-0.0617***	0.0158	IV	non-exporters	826,072	350
Revenue TFP, fixed effects	-0.0322***	0.0028	OLS	all	1,037,738	-
Revenue TFP, fixed effects	-0.0477***	0.0184	IV	all	1,037,738	278
Revenue TFP, fixed effects	-0.0580***	0.0170	IV	non-exporters	826,072	350
Panel B						
new product share	-0.000356	0.0012	OLS	all	1,037,738	-
new product share	-0.0157**	0.0068	IV	all	1,037,738	278
new product share	-0.00976**	0.0045	IV	non-exporters	826,072	350
0-1 dummy for introducing new products	-0.000687	0.0029	OLS	all	1,037,738	-
0-1 dummy for introducing new products	-0.0405**	0.0168	IV	all	1,037,738	278
0-1 dummy for introducing new products	-0.0279***	0.0102	IV	non-exporters	826,072	350
Panel C						
Sector ranking in skill intensity	-17.82***	1.00	OLS	all	1,037,738	-
Sector ranking in skill intensity	-26.20***	3.81	IV	all	1,037,738	278
Sector ranking in skill intensity	-18.80***	3.14	IV	non-exporters	826,072	350
(higher ranking corresponds to higher skill intensity)						

The table reports the coefficient on log of tariffs from (1). Standard errors are clustered by firm and initial sector. All regressions contain fixed effects for firm and time, and the control variables summarized in the text. TFP regressions in Panel A also include two-digit sector and 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 $p < 0.1$. [1] "All" indicates all establishments excluding SOE's and multinationals. "Non-exporters" is the subsample of these establishments that do not export.

Greater import competition, captured through tariff cuts, is associated with increases in revenue TFP, the introduction of new goods, and shifts toward skill-intensive sectors.

Using the IV specification with all establishments in Panel A, a one standard deviation in log of tariffs, around 0.5, is associated with an increase in revenue TFP by about 2.5 percent (0.5 × 0.5). In Panel B, it is associated with an increase of 0.8 percentage points in the share of new products in total sales (0.5 × -0.0157), and with an increase of 2 percentage points in the probability of introducing a new product (0.5 × -0.0405).

In Panel C, the dependent variable is the ranking of sectors in ascending order of skill intensity. Since all specifications include firm fixed effects, the identification stems from firms switching sectors, approximately 15 percent of firms in the sample. With point estimates ranging from -18 to -26, a one standard deviation reduction in log tariffs is associated with a movement up the rank of 9 to 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), from steel rolling processing (3230) to the manufacture of metal structures (3411), and 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 To investigate 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 the regressions in Table 1 replacing log $\text{Tariff}_{j(i,t)t}$ with the log $\text{Tariff}_{j(i,t)t}$ interacted with dummies indicating the firm's quartile of sales within its sector in year $t-1$. We also add these quartile dummies as independent variables.

Table 2 reports the coefficients on the interaction terms. The dependent variable

Table 2: Responses of Firms to Output Tariff Cuts by Quartile of Sales

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

	All establishments excl. SOEs and multinationals				Only non-exporters	
	OP OLS	FE OLS	OP IV	FE IV	OP IV	FE IV
tariff*q1$_{i,t-1}$	-0.0337***	-0.0344***	-0.0334**	-0.0276	-0.0435***	-0.0365**
	(0.00341)	(0.00350)	(0.0169)	(0.0175)	(0.0167)	(0.0172)
tariff*q2$_{i,t-1}$	-0.0302***	-0.0312***	-0.0277	-0.0249	-0.0396**	-0.0353*
	(0.00313)	(0.00322)	(0.0179)	(0.0189)	(0.0173)	(0.0181)
tariff*q3$_{i,t-1}$	-0.0261***	-0.0273***	-0.00859	-0.00510	-0.0180	-0.0132
	(0.00314)	(0.00324)	(0.0190)	(0.0198)	(0.0189)	(0.0196)
tariff*q4$_{i,t-1}$ (largest)	-0.0240***	-0.0253***	-0.0129	-0.0118	-0.0259	-0.0233
	(0.00327)	(0.00340)	(0.0168)	(0.0178)	(0.0173)	(0.0182)
H0: tariff*q1 = tariff*q4 (p-value)	0.0012	0.0039	0.083	0.186	0.196	0.337
Observations (panels A, B, C)	701,765	701,765	701,765	701,765	548,283	548,283

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

	All establishments excl. SOEs and multinationals				Only non-exporters	
	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
tariff*q1$_{i,t-1}$	0.000531	-0.00138	-0.0152**	-0.0513***	-0.0123**	-0.0327***
	(0.00144)	(0.00348)	(0.00746)	(0.0184)	(0.00582)	(0.0124)
tariff*q2$_{i,t-1}$	0.000509	0.000862	-0.0169**	-0.0337*	-0.0117**	-0.0252**
	(0.00142)	(0.00328)	(0.00747)	(0.0177)	(0.00575)	(0.0120)
tariff*q3$_{i,t-1}$	0.000192	0.00117	-0.0148*	-0.0293	-0.00981	-0.0168
	(0.00153)	(0.00343)	(0.00786)	(0.0191)	(0.00612)	(0.0134)
tariff*q4$_{i,t-1}$ (largest)	-0.000867	-0.00185	-0.0189**	-0.0264	-0.0131**	-0.0290**
	(0.00179)	(0.00377)	(0.00834)	(0.0194)	(0.00628)	(0.0135)

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

	All establishments excl. SOEs and multinationals		Only non-exporters	
	OLS	IV	OLS	IV
tariff*q1$_{i,t-1}$	-17.70***	-21.31***	-18.51***	-15.49***
	(1.067)	(3.914)	(1.012)	(3.441)
tariff*q2$_{i,t-1}$	-17.62***	-19.51***	-18.32***	-13.33***
	(1.070)	(3.662)	(1.015)	(3.283)
tariff*q3$_{i,t-1}$	-17.41***	-20.63***	-18.07***	-15.17***
	(1.079)	(3.835)	(1.011)	(3.446)
tariff*q4$_{i,t-1}$ (largest)	-16.95***	-23.32***	-17.89***	-17.71***
	(1.105)	(3.890)	(1.078)	(3.499)

The table repeats the results of Table 1 substituting the independent variable tariff for an interaction of tariff with a dummy indicating the firm's quartile of sales in the sector and lagged year (q1, q2, q3, q4) plus the lagged quartiles q1, q2, q3, q4 by themselves. Standard errors are clustered by firm and initial sector. Tariffs and TFP are in logs. Appendix A.1 reports the coefficients on the other control variables.

measures revenue TFP in Panel A, the introduction of new goods in Panel B, and the ranking of sector skill intensity in Panel C. We will later refer to two findings. First, in all panels the coefficient on tariffs in the smallest quartile of firm sales is negative. Second, while there is no systematic difference among quartiles of sales in the coefficients in Panels B and C, the coefficient on tariffs generally increases with quartile of sales in Panel A. It is 40 to 160 percent larger in absolute value in the smallest relative to the largest quartile of sales, although the difference is only statistically significant in the OLS.

Existing Models It is difficult to explain Table 1 with existing models of international trade. In models in which economies of scale determine firm productivity, such as Bustos (2011), Caliendo and Rossi-Hansberg (2012), Helpman et al. (2017), tighter import competition decreases firm sales and investments in technologies among non-exporting firms. In contrast in the data, import competition captured through tariff cuts is linked to higher TFP within firms, especially among non-exporting firms (Panel A).[14] In recent models of multiproduct firms such as Bernard et al. (2011), Mayer et al. (2014) and Dhingra (2013) firms respond to tighter competition by dropping their least productive varieties, not by introducing new varieties as in Panel B.

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 data (Panel C). Starting with Feenstra and Hanson (1997), some recent models predict that trade increases the demand for skills even in developing countries through an export expansion or imported inputs and capi-

[14]Appendix A.2 analyzes the relation between revenue and TFP. In Table A.10, TFP and revenue are correlated, even after controlling for time and sector fixed effects. In Table A.9, tariff cuts are associated with decreases in sales in the OLS specification. The effect is larger for non-exporting firms. These patterns are consistent with the models above and with previous findings.

Typically in models with endogenous markups, Bernard et al. (2003a), Atkeson and Burstein (2008), and Melitz and Ottaviano (2008), tighter competition decreases markups within firms, similar to the predictions of the models with economies of scale above. In Impullitti and Licandro (2017), import competition may lead to sufficient exit of domestic firms for competition to be looser for surviving plants. This is also true in our model, but our results hold for sufficiently large shocks that tighten competition for all firms. Dhingra (2013) combines variable markups with multi-product firms.

tal equipment.[15] Our empirical results, however, exploit variations in tariffs imposed by China and hold for the subsample of non-exporting firms, suggesting that import competition also plays a role.

We interpret the introduction of new goods and shifts to skill-intensive sectors as proxies for product innovation. We propose a stylized model where import competition increases product innovation. Although it would be simple to add skills to the model, we do not add them to keep the focus on innovation. To address revenue TFP, a measure of the ratio of revenue to cost (equation (2)), our setup features endogenous markups. We first present the model of a closed economy to highlight the main mechanisms.

3 A Closed Economy

3.1 Model of the Closed Economy

The set up is here and the results are in Section 3.2. Labor is the unique input into production. Households inelastically supply their labor to a perfect labor market. We normalize the total labor endowment to one, and take wages to be the numeraire. There is a continuum of sectors $S \in [0, 1]$, each containing a finite and exogenous set of firms. Firms are heterogeneous in unit costs. Each firm produces a single variety. Consumers have standard nested CES preferences, and firms discrete choices determine the partition of non-exiting firms into nests.

Firms Each firm i chooses among three discrete choices: (i) to exit, (ii) to produce a less-differentiated variety, or (iii) to produce a differentiated variety. If the firm exits, it gets zero profits. All less-differentiated varieties in sector S are in the same nest, denoted with $\mathcal{L}_S$. Each differentiated variety i has its own nest $\{i\}$. This choice between (ii) and (iii) is our only departure from the Atkeson and Burstein (2008) model.

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

If firm i is less-differentiated, it pays a fixed cost f_L and a per-unit cost c_{iL}. If it is differentiated, its fixed cost is f_D and its unit cost is c_{iD}.

Demand We write $i \in n$ whenever firm i is in nest n and $n \in S$ whenever nest n is in sector S. Spending on a variety with price p in nest n is

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

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

$$\overline{P} = \left[\int_0^1 \sum_{n'\in S} P_{n'}^{1-\eta} dS\right]^{\frac{1}{1-\eta}}, \tag{5}$$

y is total spending. The elasticity of substitution between nests is η, irrespective of whether nests are in the same sector or not for simplicity. The elasticity of substitution between varieties within a nest is σ. Assume $\sigma > \eta > 1$. For differentiated firms, $P_n = p$, and in (3) demand reduces to $x(p,n) = (p/\overline{P})^{1-\eta} y$.

Game within a Sector In ascending order of costs c_{iL}, each firm in sector S decides among the three discrete choices above (i) exit, (ii) less-differentiation, and (iii) differentiation. Once all discrete choices are made, firms simultaneously set prices. We consider the subgame perfect equilibrium (SPE).[16]

We solve for the SPE by backward induction. Consider first prices and payoffs after all discrete choices are made. From (3), firm i in nest n with unit cost c solves

$$\max_p \quad \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma}(p-c)y \tag{6}$$

$$\text{subject to} \quad P_n = \left(p^{1-\sigma} + \sum_{i'\in n, i'\neq i} p_{i'}^{1-\sigma}\right)^{1/(1-\sigma)}.$$

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

The firm best responds to the prices of other firms in its nest. 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 within nest σ and the elasticity across nests η, where the weight s is the firm's market share in revenue.

If the firm i is differentiated, $s=1$ and $\epsilon=\eta$. Its operating profit (6) is

$$\pi_D(c_{iD}) = \frac{\overline{P}^{\eta-1}}{\eta}\left(\frac{\eta c_{iD}}{\eta-1}\right)^{1-\eta} y. \tag{8}$$

Equation (7) implicitly defines the vector of prices in a nest as a function of unit costs. Define $P_L(\mathbf{c})$ as the price index (4) of a nest with a vector of unit costs $\mathbf{c}$ and $P_L(\mathbf{c})=\infty$ if $\mathbf{c}=\emptyset$, and define $\epsilon_L(c,\mathbf{c})$ as the elasticity of demand (7) of a firm with unit cost c when the vector of unit costs of the other firms in its nest is $\mathbf{c}$. When firm i does not differentiate and the vector of other firms' unit costs in $\mathcal{L}_S$ is $\mathbf{c}_{-iL}$, its operating profit (6) is

$$\pi_L(c_{iL},\mathbf{c}_{-iL}) = \overline{P}^{\eta-1}\frac{P_L(\{c_{iL},\mathbf{c}_{-iL}\})^{\sigma-\eta}}{\epsilon_L(c_{iL},\mathbf{c}_{-iL})}\left(\frac{c_{iL}\epsilon_L(c_{iL},\mathbf{c}_{-iL})}{\epsilon_L(c_{iL},\mathbf{c}_{-iL})-1}\right)^{1-\sigma} y. \tag{9}$$

Name firms in sector S according to their rank $c_{1L}\leq\ldots\leq c_{m_S L}$. Denote an action of firm i with $g_i\in\{$*exit*, *less differentiation*, *differentiation*$\}$. A vector of actions $(g_1,\ldots,g_{m_S})$ determines the sets of exiting, less-differentiated, and differentiated firms. By backward induction, starting with the least productive firm, for $i=m_S,\ldots,1$ and all possible actions $(\tilde{g}_1,\ldots,\tilde{g}_{i-1})$, firm i chooses among three subgames with starting nodes $(\tilde{g}_1,\ldots,\tilde{g}_{i-1},g_i)$ for $g_i=$ *exit*, *less differentiation*, *differentiation*. Since it anticipates the actions of firms

$i+1, ..., m_S$ following $(\tilde{g}_1, ..., \tilde{g}_{i-1}, \textit{less differentiation})$, it anticipates its competitors' costs $\mathbf{c}_{-iL}$ in $\mathcal{L}_S$. The firm then picks $\max\{0, \pi_L(c_{iL}, \mathbf{c}_{-iL}) - f_L, \pi_D(c_{iD}) - f_D\}$. These decisions are unique in every node up to a perturbation of parameters. So, the subgame perfect equilibrium is also unique up to a perturbation. Throughout, we ignore these indifference cases and cases in which two or more firms have the same unit cost c_{iL} or c_{iD}.

Sectoral Aggregation and Equilibrium The only distinction among sectors is the set of firms with their corresponding unit costs. Rank firms in each sector by ascending order of unit costs under less-differentiation, c_{iL}. Let $\tilde{i}(r, S)$ be the r^{th} ranked firm in sector S. Sector S is then characterized by a number of firms m_S, and costs $(c_{\tilde{i}(1,S)L}, ..., c_{\tilde{i}(m_S,S)L})$ and $(c_{\tilde{i}(1,S)D}, ..., c_{\tilde{i}(m_S,S)D})$. Assume that these cost vectors are bounded below by some $\underline{c} > 0$ and that they are continuous in $S \in [0, 1]$ in all but at most a finite number of sectors in which m_S may change.

All sectors are in SPE. The set of nests in sector S is one nest $\{i\}$ for each $i \in \mathcal{D}_S$ plus $\mathcal{L}_S$ if $\mathcal{L}_S \neq \emptyset$, where $\mathcal{D}_S$ is the set of differentiated firms in sector S. Let $\mathbf{c}_{LS}$ be the vector of unit costs in the less-differentiated nest $\mathcal{L}_S$. The price index in (5) is

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

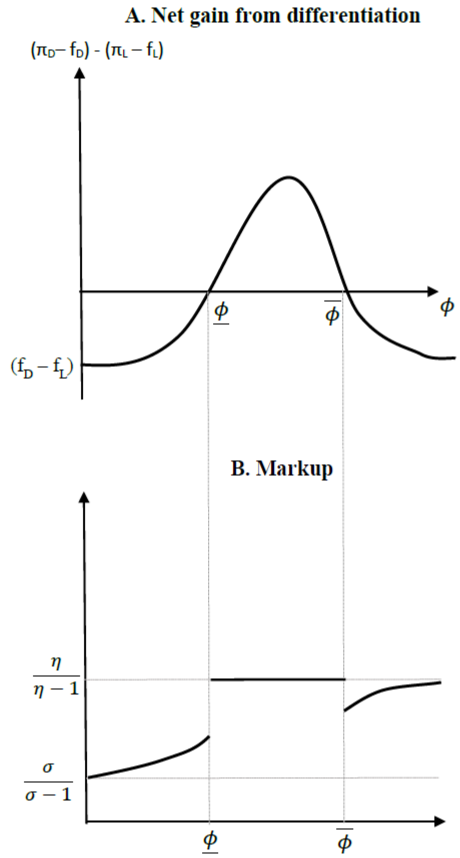
The representative household gets income from wages and profits:

$$y = 1 + \int_0^1 \left[\sum_{i \in \mathcal{L}_S} \pi_L(c_{iL}, \mathbf{c}_{-iL}) + \sum_{i \in \mathcal{D}_S} \pi_D(c_{iD}) \right] dS. \tag{11}$$

Given the assumptions on costs, the terms inside the integrals in (10) and (11) are bounded, and they are continuous in S in all but a zero-measure set of sectors where $\mathcal{L}_S$ or $\mathcal{D}_S$ change exogenously or endogenously through firms' discrete choices. Hence, the integrals exist when all sectors are in SPE.

An equilibrium is a set of firm strategies, a price $\overline{P}$, and an income y such that all

Figure 1: Example of a firm's profit from differentiation and markups ($\phi = c_{iD}^{-1} = c_{iL}^{-1}$)



sectors are in subgame perfect equilibrium, and equations (10) and (11) hold.

3.2 Results in the Closed Economy

Exit Because more productive firms move first, if firms can be ranked in terms of costs, $c_{iD} < c_{i'D}$ if and only if $c_{iL} < c_{i'L}$ for all i in sector S, then there exists $\bar{c}_S > 0$ such that firms in S produce if and only if $c_{iL} \leq \bar{c}_S$. (See proof in Appendix B.1.)

Productivity and differentiation The effect of changes in unit costs on a firm's decision to differentiate its product is straightforward: An efficient firm disproportionately gains if $c_{iD} < c_{iL}$, and loses from differentiation if $c_{iD} > c_{iL}$.[17] So to isolate the novel

[17]Innovation is often modelled as a fixed cost to decrease unit costs—e.g, Lileeva and Trefler (2010) and Bustos (2011). Differentiation involves the same considerations in the special case $f_D > f_L$ and $c_{iD} < c_{iL}$. We deal with the cases $c_{iL} \gtrless c_{iD}$ in Appendix B.3.

mechanism, assume for the moment $c_{iD} = c_{iL} \equiv c_i$ and $f_D > f_L$ (to make the firm's choice non-trivial). Fix the level of competition that firm i faces in a particular subgame, $\mathbf{c}_{-iL}$, and vary the firm's productivity $\phi \equiv (c_i)^{-1}$.

Figure 1 illustrates this exercise. It plots the net profit from differentiation $\pi_D(c_i) - \pi_L(c_i, \mathbf{c}_{-iL}) - (f_D - f_L)$ in Panel A and markups in Panel B as functions of ϕ. The net profit is $(f_L - f_D) < 0$ when $\phi = 0$ because $\lim_{c_i \to \infty} \pi_D(c_i) = \lim_{c_i \to \infty} \pi_L(c_i, \mathbf{c}_{-iL}) = 0$. Appendix B.3 proves convexity of the set of productivities ϕ with a positive net profit.

The limit $c_i \to 0$ is more didactic. Let $p_{iD} = \eta c_i/(\eta - 1)$ be the price under differentiation, and P_{-iL} be the CES price index in nest $\mathcal{L}_S$ excluding firm i from the sum, where we omit its argument $(c_i, \mathbf{c}_{-iL})$.[18] Then

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

The second line is the operating profit of a hypothetical, differentiated firm that charges $\left[P_{-iL}^{1-\sigma} + p_{iD}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \leq p_{iD}$ 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 $P_{-iL} < \infty$. Rearranging and taking limits,

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

In words, the gain in operating profit from differentiation is bounded above by the profit from acquiring the residual demand of competitors in nest $\mathcal{L}_S$. Since this residual demand

[18]
$$
P_{-iL} = \left(\sum_{i' \in \mathcal{L}, i' \neq i} p_{i'}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}
$$
where prices $p_{i'}$ are implicitly defined in (7) when the productivity vector in $\mathcal{L}_S$ is $(c_i, \mathbf{c}_{-iL})$.

goes to zero as the firm's own cost c_i goes to zero, the gain must also go to zero.[19]

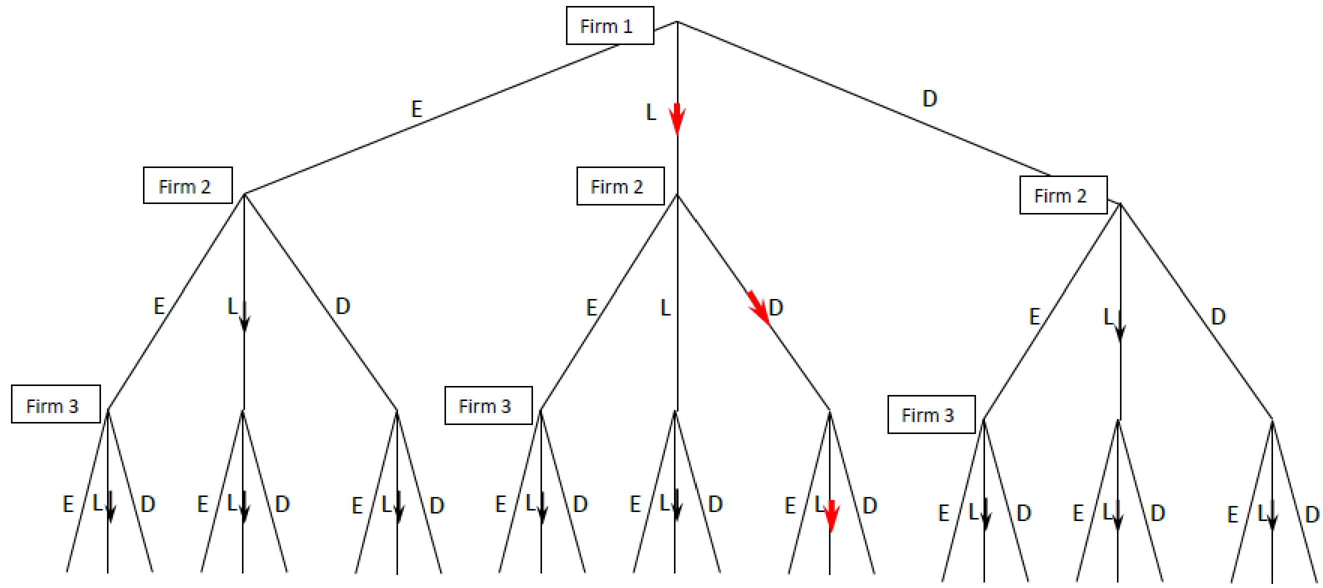
Small Shocks to Competition in Sector S Sector S is in SPE. The unit cost c_{iL} decreases for some firm $i \in S$. All firms adjust their strategies to a new SPE. If the shock is small, we show with an example that it has an ambiguous effect on the discrete actions of other firms in the same sector due to strategic interactions among firms.

There are three firms with unit costs $c \equiv c_L = c_D = (1, 1.1, 1.2)$. Fixed costs are $f_L = 0.044$ and $f_D = 0.102$, and $\overline{P}^{\sigma-1}y = 1$. Figure 2(a) illustrates the equilibrium strategies and Appendix Table B1 shows all payoffs. Actions E, L, D correspond to *exit*, *less-differentiation*, *differentiation*, respectively. We chose fixed costs so that firm 3 is close to exit in the subgame following actions (L, L), $\pi_L(c_3, \{c_1, c_2\}) = 0.045 > f_L = 0.044$, and the gain from differentiation is small for firm 2, $\pi_D(c_2) - \pi_L(c_2, \{c_1, c_3\}) = 0.059 > 0.058 = f_D - f_L$. The thick red arrows indicate the actions in the equilibrium path: (L, D, L).

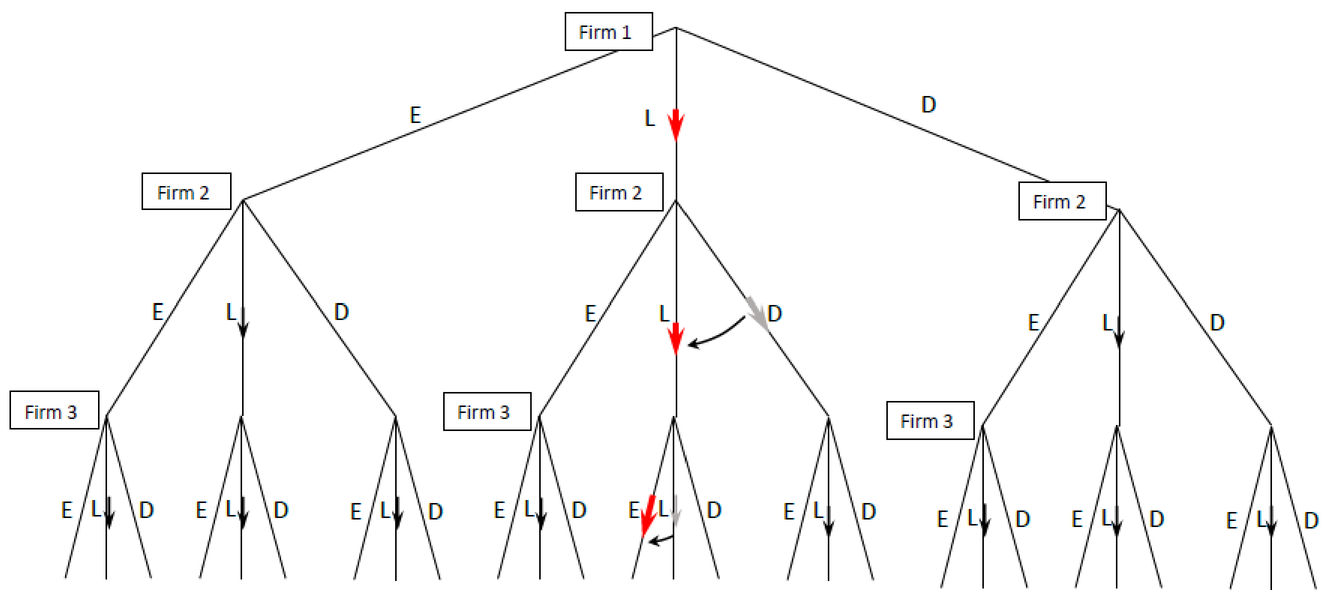
Figure 2(b) illustrates the effect on the SPE of a decrease in firm 1's cost from $c_1 = 1$ to $c_1 = 0.9$. Now, $\pi_L(c_3, \{c_1, c_2\}) = 0.041 < f_L$. Then, firm 3 exits in the subgame following actions (L, L). The gross gain from product differentiation for firm 2 becomes $\pi_D(c_2) - \pi_L(c_2, \{c_1\}) = 0.055 < f_D - f_L$. Actions in the new equilibrium path are (L, L, E). So, firm 2 switches from differentiation to less-differentiation.

Similar examples exist in which a decrease in firm i's unit cost leads some firms i' to differentiate and yet other firms i'' to switch from exiting to producing a less-differentiated variety. Examples where the shock increases exit and differentiation among other firms $i' \in S$ are easy to generate since the operating profit under less differentiation $\pi_L(c_{i'L}, \mathbf{c}_{-i'L})$ in (9) is decreasing in any element of $\mathbf{c}_{-i'L}$, while the profit $\pi_D(c_{iD})$ is unaffected by shocks to a single sector.

[19] The claim $\lim_{c_i \to 0}(\pi_D - \pi_L) = 0$ is trivial in the limiting case $\sigma = \infty$ in Bernard et al. (2003b). The price is the minimum between the second lowest cost and the monopoly price. When the firm is sufficiently productive to charge monopoly price, $\pi_D(c_{iD}) = \pi_L(c_{iL}, \mathbf{c}_{-iL})$. We thank Samuel Kortum for pointing out this case.



(a) Initial SPE



(b) SPE after shock (decrease in c_1)

Figure (a) illustrates the SPE when $\overline{P}^{\sigma-1}y = 1$, costs are $c_L = c_D = (1, 1.1, 1.2)$ and fixed costs are $f_L = 0.044$, $f_D = 0.102$. Letters E, L, D indicate actions exit, less-differentiation, and differentiation, respectively. The arrows indicate all equilibrium strategies and the thick arrows indicate the actions in the equilibrium path. Figure (b) illustrates how the subgame perfect equilibrium changes when the c_1 decreases from 1 to 0.9. Firm 2 switches from a differentiated to a less-differentiated product because it knows that firm 3 will exit in the subgame following actions (L,L) by firms 1 and 2.

Figure 2: Example of the effect of a small decrease in c_1 on the SPE strategies

Large Shocks to Competition in Sector S. The key statistic summarizing the level of competition that firm i faces in the less-differentiated nest is

$$P_{-\bullet L}(c_{iL}, \mathbf{c}_{-iL}) = \left(\sum_{i' \in \mathcal{L}_S, i' \neq i} p_{i'}^{1-\sigma} \right)^{1/(1-\sigma)} \tag{12}$$

where $\mathbf{c}_{-iL}$ is the vector of unit costs in $\mathcal{L}_S$, excluding firm i, in the subgame in which firm i is less differentiated and all other firms play their SPE strategies. The operating profit in (6) depends on $\mathbf{c}_{-iL}$ only through $P_{-\bullet L}(c_{iL}, \mathbf{c}_{-iL})$. In the example of Figure 2, $P_{-\bullet L}(c_{2L}, \mathbf{c}_{-2L})$ increased with the decrease in c_1.

A decrease in c_{iL} for some firm i in sector S is sufficiently large if it decreases the SPE value of $P_{-\bullet L}(c_{i'L}, \mathbf{c}_{-i'L})$ for all $i' \neq i$ in sector S. With a finite number of firms in sector S, it is always possible to construct such shocks since $P_{-\bullet L}(c_{i'L}, \mathbf{c}_{-i'L}) < \eta c_{iL}/(\eta - 1)$ for all $i' \neq i$, when firm i chooses less-differentiation in all subgames.

A sufficiently large decrease in c_{iL} increases differentiation and exit among firms $i' \neq i$ and $i' \in S$. Among surviving firms, the shock decreases the markup of firms that remain less-differentiated, and it increases the markup of newly-differentiated firms. If two firms $a, b \neq i$ have costs $c_{aL} < c_{bL}$ and they are in $\mathcal{L}_S$ in the initial SPE, the decrease in c_{iL} increases the markup of firm b relative to firm a if both firms a and b remain in $\mathcal{L}_S$ or if they both differentiate their products in the new SPE.

This last claim is trivial when both firms differentiate, because markups of a and b go to $\eta/(\eta-1)$, and markups in $\mathcal{L}_S$ are strictly decreasing in costs $c_{i'L}$ in any SPE. Appendix B.4 proves the case in which firms a and b remain in $\mathcal{L}_S$, and they best respond to the shock and to other endogenous price changes. We only note that tighter competition in $\mathcal{L}_S$ cannot decrease the markups of small firms beyond the lower bound $\sigma/(\sigma - 1)$.

Shock to Competition in a Non-Zero Mass of Sectors. An economy is in equilibrium. The unit cost c_{iL} of a non-zero measure of firms decreases. Denote the set of firms affected by the shock with $\mathcal{I}$ and the subset of sectors with $\mathcal{S}$. The shock is such that the vectors of costs after the shock are still bounded from below and continuous almost everywhere. The economy adjusts to a new equilibrium.

Assume that the shock is large enough to decrease $\overline{P}^{\eta-1}y$, and to decrease $P_{-\bullet L}(c_{iL}, c_{-iL})$ for all firms $i \notin \mathcal{I}$ in a sector $S \in \mathcal{S}$. A large enough shock decreases $\overline{P}^{\eta-1}y$ because the profit share of the economy is bounded, and the shock can make $\overline{P}$ arbitrarily small. A large shock satisfies the second condition because the number of firms in each sector is finite and costs are bounded, and so the initial $P_{-\bullet L}(c_{iL}, c_{-iL})$ is also bounded.

For firms in a sector $S \in \mathcal{S}$ but not in $\mathcal{I}$, the shock increases exit. It increases differentiation if $f_D \leq f_L$. The effect of the shock on the ratio $\pi_D(c_{iD})/\pi_L(c_{iL}, c_{-iL})$ is the same as in the single-sector shock above. The additional condition $f_D \leq f_L$ arises because the general equilibrium decrease in $\overline{P}^{\eta-1}y$ decreases profits π_D and π_0. So, it decreases the incentives for firms to make costly investments, as in standard models.

The shock only affects firms in a sector $S \notin \mathcal{S}$ through its decrease in $\overline{P}^{\eta-1}y$. Like in the case of small sectoral shocks, the shock has an ambiguous effect on discrete choices. In general, a decrease in $\overline{P}^{\eta-1}y$ increases exit, and it increases differentiation if $f_D < f_L$. But because firms interact strategically, the increase in exit may push some originally-differentiated firms to switch to less-differentiation, and differentiation among some firms may push originally-inactive firms to enter the less-differentiated nest.

We have derived conditions for a shock to competition in the less-differentiated nest(s) to push firms to exit and to escape to new nests. These shocks are akin to shocks to international trade in the open economy model below.

4 A Small Open Economy

4.1 Model of the Open Economy

We present the set up here and the results in section 4.2. Section 4.3 uses the model to revisit the empirical findings. Home is a small country that trades with large Foreign.

Labor is the only input into production. Home households sell their one unit of labor in a perfect labor market with wage one. Their demand is in (3). There is an exogenous set of sectors $S \in [0,1]$, each with a finite set of Home and Foreign firms. The choices and the technologies of Home firms, when serving the Home market, are as in Section 3. Home firms may also export.

Foreign firms Each Foreign firm i chooses between *two* discrete choices: (i) to exit the Home market, or (ii) to supply Home with a less-differentiated variety. All less-differentiated varieties of sector S, foreign and domestic, are in the same nest $\mathcal{L}_S$.

If Foreign firm i exits, it gets zero profits. Otherwise, it pays a fixed cost $w^* f_L^*$ and a cost $c_{iL} = w^* c_{iL}^*$ for each unit of its variety delivered in Home, where w^* is the Foreign wage. Rank foreign firms in each sector by ascending order of unit costs c_{iL}. Let m_S^* be the number of foreign firms in sector S and $i^*(r,S)$ be the r^{th} ranked foreign firm in sector S. Assume $(c_{i^*(1,S)L}, ..., c_{i^*(m_S^*,S)L})$ is bounded below by some $\underline{c} > 0$ for all S, and that they are continuous in S in all but at most a finite number of sectors.

Sectoral Game in the Open Economy In ascending order of costs c_{iL}, each firm in sector S makes its discrete choice. Home firms decide among (i) exit, (ii) less-differentiation, and (iii) differentiation. Foreign firms decide between (i) exit and (ii) less-differentiation. Once all discrete choices are made, firms simultaneously set prices.

The solution to the subgame perfect equilibrium (SPE) in the open economy is similar to the closed economy game. The pricing rule is in (7). Given a set of actions, the operating profit of firm i is $\pi_L(c_{iL}, \mathbf{c}_{-iL})$ in (9) if the firm is less differentiated, and it is $\pi_D(c_{iD})$ in (8) if the firm is differentiated. The fixed cost is $w^* f_L^*$ for Foreign firms. It is f_L for less-differentiated Home firms and f_D for differentiated firms. Given payoffs, the equilibrium discrete actions are found by backward induction starting with the least productive firm. As before, the SPE is unique up to a perturbation of parameters.

Home exports We take the simplest possible setting since our empirical application does not pertain to exports. In addition to supplying Home, domestic firms may export to Foreign. If firm i exports, it incurs a fixed cost f^* units of labor, and its sales and net profits from exporting are respectively

$$X^*(c_{iL}, w^*) = (c_{iL}/w^*)^{1-\sigma} w^* Y^*, \qquad (13)$$
$$\pi^*(c_{iL}, w^*) = \frac{X^*(c_{iL}, w^*)}{\sigma} - f^*$$

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

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

Equilibrium in the Open Economy All sectors are in SPE. Let S_H^* be the set of Home firms in sector S that export, $\mathcal{L}_{HS}$ be the set of less-differentiated Home varieties, and $\mathcal{L}_{FS}$ be the set of Foreign varieties producing for Home, $\mathcal{L}_{HS} \cup \mathcal{L}_{FS} = \mathcal{L}_S$.

The expression for the price index $\overline{P}$ in (10) does not change. Household income is

$$y = 1 + \int_0^1 \left[\sum_{i \in S_H^*} \pi^*(c_{iL}, w^*) + \sum_{i \in \mathcal{D}_S} \pi_D(c_{iD}) + \sum_{i \in \mathcal{L}_{HS}} \pi_L(c_{iL}, \mathbf{c}_{-iL})\right] dS. \qquad (14)$$

Trade balances if

$$\int_0^1 \sum_{i \in S_H^*} X^*(c_{iL}, w^*) dS = \overline{P}^{\eta-1} y \int_0^1 \sum_{i \in \mathcal{L}_{FS}} P_L(\mathbf{c}_{LS})^{\sigma-\eta} \left(\frac{c_{iL}\epsilon_L(c_{iL}, \mathbf{c}_{-iL})}{\epsilon_L(c_{iL}, \mathbf{c}_{-iL}) - 1}\right)^{1-\sigma} dS. \qquad (15)$$

Given the assumptions on costs, integrals (10), (14) and (15) exist when all sectors are in SPE. An equilibrium of the open economy is a set of firm strategies, Foreign wages w^*, price index $\overline{P}$, and income y such that all sectors are in SPE, and (10), (14) and (15) hold.

4.2 Shocks to International Trade

The economy is in equilibrium. The cost parameters c^*_{iL} decrease for all Foreign firms in sector S, and firms in sector S change their strategies to a new SPE. Following Section 3.2, if the shock is small, it has an ambiguous effect on Home firms' discrete choices.

If the shock is large, it increases exit and differentiation among Home firms in sector S. Among surviving firms, the markup decreases for firms that remain less-differentiated, and it increases for firms that switch to differentiation. If two firms a and b with $c_{aL} < c_{bL}$ are initially less-differentiated, then the markup of firm b increases relative to firm a if both firms remain in $\mathcal{L}_S$ or if they both differentiate.

A large reduction in the costs of foreign firms in a non-zero measure of sectors $\mathcal{S} \subset [0,1]$ increases exit and differentiation of Home firms in sectors $S \in \mathcal{S}$ if $f_D \leq f_L$. For sectors $S \notin \mathcal{S}$ the shock has an ambiguous effect on discrete choices.[20]

4.3 Empirical Results through the Lenses of the Model

We interpret differentiation as domestic firms' strategies to insulate themselves from foreign competition, through tailoring goods to domestic tastes, offering greater customization, and bundling products with non-tradable services. This interpretation justifies our assumption that foreign firms cannot offer differentiated varieties. Nothing in the model changes if we allow for the existence of nests that are supplied only by foreign firms, such as market niches with luxuries and high-tech goods.[21] The key assumption is that import competition decreases the profits from producing more standardized, tradable varieties relative to less-tradable, customizable varieties for domestic firms.

Since differentiation is not directly observed, we take the introduction of new goods and shifts to skill-intensive four-digit sectors as proxies. In the examples of the introduction,

[20] In the open economy, the shock that affects a non-zero measure of sectors has the additional effect of increasing Foreign wages w^*, which generally loosens competition in $\mathcal{L}_S$ for $S \notin \mathcal{S}$.

[21] A decrease in the price index of these nests has the same general equilibrium effects of decreasing $\overline{P}^{\eta-1}y$ as decreases in the cost of foreign varieties in $\mathcal{L}_S$.

Chery Automobiles and cell-phone maker Xiaomi shifted toward skill-intensive tasks in their response to import competition.

Our empirical results exploit cross-sectoral variation in tariff changes. We interpret tariff cuts in individual sectors in the data as a reduction in the cost of Foreign varieties c^*_{iL} in a single sector S in the model. If this reduction is large, it increases exit and product differentiation in Home. Consistent with these predictions, tariff cuts are associated with the introduction of new goods and shifts toward skill-intensive sectors. In Appendix Tables A7 and A8, tariff cuts are also associated with exit from the survey and with switches in four-digit sectors.

Revenue TFP in equation (2) is an estimate of the ratio of revenue to costs which corresponds to the markup in the model. In Table 2, tariff cuts are associated with similar changes in the probability of switching to skill-intensive sectors or to introduce new goods. In the model, if two firms of different sizes make the same discrete choice in response to a trade shock, as suggested by this finding, then the markup of the smaller firm increases relative to the large firm. In line with this prediction, the coefficient on tariffs generally increases with firm size when the dependent variable in revenue TFP.

This interpretation of TFP is valid as long as revenue TFP is correlated with the true unobserved revenue to cost ratio in the data. But two points are in order. First, measures of TFP generally assume a Markov path for productivity, Hicks neutrality, and product homogeneity. These assumptions 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.[22] The usual decomposition of revenue TFP into quantity TFP and prices is not applicable because varieties in the model are differentiated and costs c_{iL} and c_{iD} are quality-adjusted like in Melitz (2003).[23]

[22]Harrison (1994), De Loecker (2007) and De Loecker and Warzynski (2012) make similar points on changes in demand during trade reforms. DeLoecker et al. (2016) allow for vertically-differentiated goods, but maintain the other assumptions above. Recent papers relax the assumption of Hicks neutral technologies and allow for skill-biased technical change in productivity measures, e.g., Bøler (2019), Harrigan et al. (2019). We cannot apply their methods because we do not observe worker skills.

[23]For recent work on this decomposition, see Ackerberg et al. (2015), DeLoecker et al. (2016), and

Second, even if revenue productivity perfectly measured the ratio of revenue to cost, it would still be a poor proxy for product differentiation. This ratio confounds the positive effect of differentiation on markups with the negative effect of greater competition on firms that do not differentiate.

The Chinese accession to the WTO was a large trade liberalization. Average tariffs on manufacturing in China fell from 43 percent in 1992 to 9.4 percent in 2004, while imports as a share of GDP more than doubled from 12 to 28 percent. In the model, large and widespread decreases in foreign costs increase differentiation if $f_D \leq f_L$. Table 2 shows that small firms in sectors with larger tariff cuts increased revenue productivity, the introduction of new goods and switches to skill-intensive sectors relative to small firms in other sectors. The model can only rationalize these findings if differentiation does not involve large fixed costs, $f_D \approx f_L$. So, they suggest, through the lenses of the model, that the WTO accession increased overall product differentiation in China, not just in some sectors relative to others. Next, we investigate the welfare effects of such differentiation.

5 Differentiation and Welfare

It is well-known that heterogeneous markups lead to misallocation of labor because the consumer chooses quantities based on prices, and the planner does it based on costs. Appendix C proves that, given a set of discrete choices, the planner allocates relatively more labor to differentiated than to less-differentiated varieties compared to the market. And within less-differentiated nests, the planner allocates more labor to more productive varieties.[24]

Gandhi et al. (2017). As Foster et al. (2008) explain, these methods apply to sectors with homogeneous goods, where quantity TFP is meaningful.

[24]See Edmond et al. (2015) for missallocation in the Atkeson and Burstein (2008) model. Take two domestic varieties $i, i' \in \mathcal{L}_{HS}$. From standard CES maximization, labor allocations satisfy

$$\frac{\text{labor}_i^{\text{planner}}}{\text{labor}_{i'}^{\text{planner}}} = \left(\frac{c_{iL}}{c_{i'L}}\right)^{-\sigma} > \left(\frac{c_{iL}/\mu_{iL}}{c_{i'L}/\mu_{i'L}}\right)^{-\sigma} = \frac{\text{labor}_i^{\text{market}}}{\text{labor}_{i'}^{\text{market}}}.$$

We focus on the more novel results on discrete choices. Section 5.1 evaluates the marginal welfare effects of a single variety. Section 5.2 studies changes in the discrete choices of a non-zero mass of firms.

5.1 Marginal Welfare Effect of a Firm's Discrete Choice

Sector S is in a subgame after all discrete choices are made. A planner can change a single firm's discrete choice. Prices maximize profits and quantities clear markets before and after the shock. We compare the social benefit of a variety to the private profit.

The marginal cost of labor in the economy is $C = wK/Q$ where Q is the standard aggregate quantity, $Q = y/\overline{P}$, and K is labor allocated for production[25]

$$K = 1 - \int_0^1 \left(\left|\mathcal{L}_{HS}\right| f_L + \left|\mathcal{D}_S\right| f_D + \left|S_H^*\right| f^*\right) dS$$

where $|x|$ denotes the number of elements in set x. Define the average markup as $\overline{\mu} = \overline{P}/C$, price over marginal cost.

By Roy's identity, the valuation of a differentiated variety $i \in \mathcal{D}_S$ for a planner who cannot determine prices or quantities is:

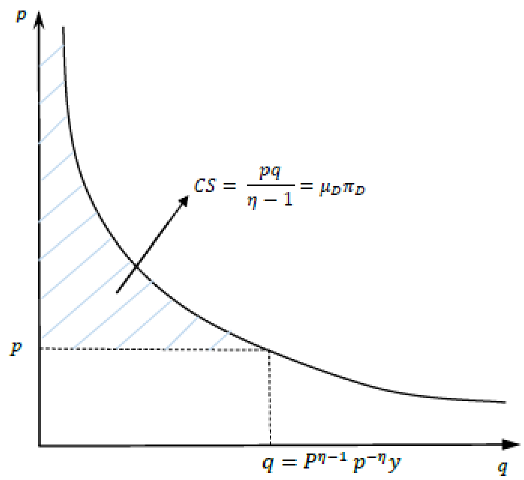
$$u_D(c_{iD}) = \overline{P}^{-1} \underbrace{\int_{\mu_D c_{iD}}^{\infty} q_D(p)dp}_{\text{consumer surplus}} - C^{-1} f_D \tag{16}$$

The planner allocates more labor to the variety with the higher markup μ_{iL} compared to the market. The proof for allocation of labor between nests follows a similar reasoning.

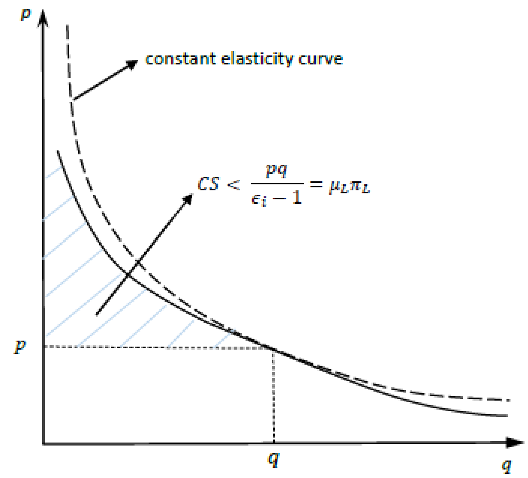
[25] The expression $C = K/Q$ holds because net of fixed costs, the economy exhibits constant returns to scale. Net of fixed costs, international trade also effectively transforms labor into imports with constant returns. Aggregate quantity with nested CES is:

$$Q = \left[\int_0^1 \sum_{n \in S} Q_n^{(\eta-1)/\eta} dS\right]^{\eta/(\eta-1)}$$

$$\text{where} \quad Q_n = \left[\sum_{i \in n} q_i^{(\sigma-1)/\sigma}\right]^{\frac{\sigma}{\sigma-1}}.$$



(a) Differentiated Variety



(b) Less-Differentiated Variety

Figure 3: Consumer surplus terms (CS) in equations (16) and (18)

where $\overline{P}^{-1}$ is the marginal utility of income, $\mu_D = \eta/(\eta-1)$ is the differentiated markup, and $q_D(p')$ is the demand function. Substituting $q_D(p) = \overline{P}^{\eta-1} y p^{-\eta}$ from (3), the integral in (16) becomes $\mu_D \pi_D(c_{iD})$ and

$$\begin{aligned} u_D(c_{iD}) &= \overline{P}^{-1} \mu_D \pi_D(c_{iD}) - C^{-1} f_D \\ &= C^{-1} \left[\left(\frac{\mu_D}{\overline{\mu}} \right) \pi_D(c_{iD}) - f_D \right] \\ &\geq C^{-1} [\pi_D(c_{iD}) - f_D] \end{aligned} \tag{17}$$

because $\mu_D \geq \overline{\mu}$. Figure 3(a) illustrates the consumer surplus.

For a less-differentiated domestic variety i, define $q_L(p', \mathbf{p}_{-iL})$ as its residual demand when its price is p' and its competitors' prices are at their subgame equilibrium level, vector $\mathbf{p}_{-iL}$ with elements $p_{i'L}$. From (3),

$$q_L(p', \mathbf{p}_{-iL}) = \overline{P}^{\eta-1} y \left((p')^{1-\sigma} + \sum_{i' \in \mathcal{L}_S, i' \neq i} (p_{i'L})^{1-\sigma} \right)^{\frac{\sigma-\eta}{1-\sigma}} (p')^{-\sigma}.$$

Define $\tilde{q}_i(p) = Ap^{-\epsilon}$ as a hypothetical demand function where ϵ is the endogenous elasticity of demand of the firm in equilibrium, $\tilde{q}_i(\mu_{iL}c_{iL}) = q_L(\mu_{iL}c_{iL}, \mathbf{p}_{-iL})$ and $\mu_{iL} = \epsilon/(\epsilon-1)$. These demand functions are illustrated in Figure 3(b). The dashed line of $\tilde{q}_i(p)$ is above the solid line of $q_L(p', \mathbf{p}_{-iL})$, because the elasticity of demand in (7) is strictly increasing in the firm's price.

Since these demand functions are implicit functions of unit costs in $\mathcal{L}_S$, $(c_{iL}, \mathbf{c}_{-iL})$, we write the contribution of variety i to welfare as

$$u_L(c_{iL}, \mathbf{c}_{-iL}) \leq \overline{P}^{-1} \underbrace{\int_{\mu_{iL}c_{iL}}^{\infty} q_L(p', \mathbf{p}_{-iL})dp'}_{\text{consumer surplus}} - C^{-1}f_L \tag{18}$$

$$\leq \overline{P}^{-1} \int_{\mu_{iL}c_{iL}}^{\infty} \tilde{q}_i(p')dp' - C^{-1}f_L$$

$$= \overline{P}^{-1} \mu_{iL}\pi_L(c_{iL}, \mathbf{c}_{-iL}) - C^{-1}f_L. \tag{19}$$

The first inequality holds because when variety i is taken out of nest $\mathcal{L}_S$, the consumer's valuation of other varieties in $\mathcal{L}_S$ increases.[26] The second inequality is the difference between the areas delineated by q_L and $\tilde{q}$ in Figure 3(b).[27] Both inequalities are strict if firm i is not a monopolist in nest $\mathcal{L}_S$.

Since $\mu_D \geq \mu_{iL}$, inequalities (17) and (19) imply that the marginal social benefit of a differentiated variety is always greater than the private profit, 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 $\mu_{iL} < \overline{\mu}$.

In sum, there are two reasons for the planner to prefer the differentiated varieties. The first is in Figure 3. The second is that the consumer surplus is calculated on the basis of prices and quantities, but the planner cares about the labor used by a variety. For a

[26] By Roy's identity, their valuation increases because their demand and prices go up.

[27] The area under this dashed line is

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

given revenue, the differentiated variety uses less labor because it has a higher markup (see inequality (17)).

5.2 Welfare and the Discrete Choices of a Set of Firms

The economy is in equilibrium. A planner selects a non-zero set of differentiated firms $\mathcal{I}$ and shifts them from differentiation to less-differentiation. Set $\mathcal{I}$ is picked so that the conditions on continuity of costs (except for a finite number of sectors) hold conditional on discrete choices. All other firms cannot change their original discrete choices. All firms then set prices to maximize profits and general equilibrium variables $(w^*, \overline{P}, y)$ simultaneously adjust to satisfy (10), (14) and (15). If the profit share in the economy decreases in the counterfactual, then welfare is lower in the counterfactual than in the original equilibrium.

Before proving this claim, we note that the results on the marginal value of varieties above do not imply that a planner would never gain from forcibly shifting a firm from differentiation to a less-differentiated nest. Such a change may correct other market distortions and increase welfare. For example, it may lead other Home firms to exit or to differentiate their products, or it may decrease the sales of less-differentiated Foreign firms. To avoid such scenarios, the counterfactual restricts the discrete choices of firms not undergoing the shock. It assumes that Home income decreases to preclude a large shift of labor from the production of exports to the production of differentiated varieties, which defeats the spirit of the counterfactual to forcibly decrease differentiation.

Proof. Suppose not, suppose real income $y/\overline{P}$ increases with the counterfactual. Then, $\overline{P}^{\eta-1}y$ must decrease because y decreases by assumption. If w^* increases, then, exports by Home firms in (23) increase. To balance trade, Foreign sales in Home must also increase. But this is a contradiction since w^* increases and $\overline{P}^{\eta-1}y$ decreases. Then,

w^* decreases. For any firm i,

$$\pi_L(c_{iL}, \mathbf{c}_{-iL}) - \pi_D(c_{iD}) =$$
$$\overline{P}^{\eta-1} y \left[\frac{1}{\epsilon(c_{iL}, \mathbf{c}_{-iL})} \left(\frac{c_{iL}\epsilon(c_{iL}, \mathbf{c}_{-iL})}{\epsilon(c_{iL}, \mathbf{c}_{-iL}) - 1} \right)^{1-\sigma} P_L(\{c_{iL}, \mathbf{c}_{-iL}\})^{\sigma-\eta} - \frac{1}{\eta} \left(\frac{c_{iD}\eta}{\eta - 1} \right)^{\eta-1} \right]$$

decreases because $\overline{P}^{\eta-1} y$ decreases and there are (weakly) more elements in $\mathbf{c}_{-iL}$ and costs $c_{iL} = w^* c^*_{iL}$ for foreign firms go down. In Section 5.1 we proved that the marginal gain from transferring a firm from differentiation to less-differentiation was larger for the firm than for the planner. Then, the only way for the planner to benefit from transferring firms from differentiation to less-differentiation is if the profits from less-differentiation increase with general equilibrium effects for at least a non-zero measure of firms in $\mathcal{I}$. This contradicts the decrease in $\pi_L(c_{iL}, \mathbf{c}_{-iL}) - \pi_D(c_{iD})$ for all i. ■

Using the model to interpret the empirical results in Section 4.3, we argued that the evidence supports the hypothesis that differentiation increased among surviving Chinese firms during China's accession to the WTO. Then, the welfare gains from the trade shock were probably larger than in a scenario in which Home firms do not have the option to differentiate, as in standard models.

A back of the envelope calculation suggests that gains from trade due to differentiation may be sizable. In Panel B of Table 1, a one standard deviation reduction in log output tariffs (around 0.5) 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 mass of differentiated products by 0.8 percent and decreasing more substitutable products by the same share increases welfare by 0.7 percent, a significant value relative to standard estimates of gains from trade.[28]

[28] Using the definition of $\overline{P}$ in (3), the estimated decrease in price is $\overline{P}^1/\overline{P}^0 \approx 1.008^{1/(1-\eta)} * 0.992^{1/(1-\sigma)}$. 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, imports as a share of GDP increased from 14% to 28% in the period of our data. Then, the

6 Input Suppliers: Evidence and Theory

6.1 Evidence on Input Suppliers

This section modifies the model to account for the input suppliers of import-competeting firms. In contrast to import-competing firms, the model has sharp predictions for the effects of trade on the markups of input suppliers that are well supported by the data. We present the evidence here, the theory in Section 6.2 and its results in Section 6.3.

Define downstream tariffs in sector j time t as a weighted average of the tariffs in the sectors downstream from sector j:

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

where α_{jk} is the share of sector j's production supplied to sector k, taken from the 2002 Chinese Input-Output table. Weights α_{jk} do not add up to one because part of output goes to final consumption. Downstream tariffs are high in sector j if some downstream sectors k have high tariffs and use a large share of sector j's output.

All our regressions control for the downstream (and input) tariffs of the firm i's sector in time t. Table 3 reports the coefficients on downstream tariffs and repeats the coefficients on output tariffs from Table 1 for comparison. In the IV specifications of panels B and C, the coefficient on downstream tariffs is negative. Tariff cuts in sectors downstream from the firm are associated with the introduction of new goods and switches to skill-intensive four-digit sectors within firms. Not surprisingly, the evidence is weaker than for firms directly impacted with the shock. The coefficient is insignificant in the regressions of new goods, and it is similar to the coefficient on output tariffs (equality cannot be rejected) in the regressions of sectoral switches.

In contrast, when the dependent variable is revenue TFP, the coefficient on down-

welfare gain in Arkolakis et al. (2012) with an elasticity $\sigma = 5$ (between 2 and 10, and no intermediate inputs) is $(0.72/0.86)^{-1/5} - 1 = 3.6$ percent.

Table 3: Regressions of Productivity, New Goods, and Sectoral Skill Intensity on Tariffs

	output tariffs		downstream tariffs				number of
dependent variable ↓	**coeff.**	**se**	**coeff.**	**se**		**sample[1]**	**observations**
Panel A							
Revenue TFP, Olley-Pakes	-0.0304***	0.0027	-0.0179**	0.0070	OLS	all	1,037,738
Revenue TFP, Olley-Pakes	-0.0505***	0.0169	-0.178***	0.0627	IV	all	1,037,738
Revenue TFP, Olley-Pakes	-0.0617***	0.0158	-0.421***	0.0650	IV	non-exporters	826,072
Revenue TFP, fixed effects	-0.0322***	0.0028	-0.0194**	0.0079	OLS	all	1,037,738
Revenue TFP, fixed effects	-0.0477***	0.0184	-0.173***	0.0641	IV	all	1,037,738
Revenue TFP, fixed effects	-0.0580***	0.0170	-0.444***	0.0672	IV	non-exporters	826,072
Panel B							
new product share	-0.00036	0.0012	-0.00372	0.0024	OLS	all	1,037,738
new product share	-0.0157**	0.0068	-0.0272	0.0184	IV	all	1,037,738
new product share	-0.00976**	0.0045	-0.0313**	0.0147	IV	non-exporters	826,072
0-1 dummy for introducing new products	-0.00069	0.0029	0.0078	0.0078	OLS	all	1,037,738
0-1 dummy for introducing new products	-0.0405**	0.0168	-0.0533	0.0399	IV	all	1,037,738
0-1 dummy for introducing new products	-0.0279***	0.0102	-0.0423	0.0266	IV	non-exporters	826,072
Panel C							
Sector ranking in skill intensity	-17.82***	1.00	6.914***	1.34	OLS	all	1,037,738
Sector ranking in skill intensity	-26.20***	3.81	-33.44***	7.40	IV	all	1,037,738
Sector ranking in skill intensity	-19.27***	3.14	-31.39***	7.49	IV	non-exporters	826,072
(higher ranking corresponds to higher skill intensity)							

The table reports the coefficients on log of output and downstream tariffs from regression (1). Standard errors are clustered by firm and initial sector. All regressions contain fixed effects for firm and time, and the control variables summarized in the text. TFP regressions in Panel A also include two-digit sector and 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 $p < 0.1$. [1] "All" indicates all establishments excluding SOE's and multinationals. "Non-exporters" is the subsample of these establishments that do not export.

stream tariffs is seven to eight times larger than the coefficient on output tariff in our preferred specification, the IV with only non-exporting establishments. This result holds in all robustness checks of Section 7. It is puzzling because non-exporting input suppliers should be affected by tariff cuts downstream only to the extent that these cuts affect their import-competing customers.

6.2 Model with Input Suppliers

The main difference from Section 4 is that the production of less-differentiated downstream firms uses labor and materials. In line with the quality literature, these firms use only less-differentiated material inputs.[29] Their unit costs c_{iL} depend on the actions of input suppliers upstream. For simplicity, differentiated firms use only labor for production.

There are two countries, Home and Foreign. Home is a small open economy. Labor, the only factor of production, is inelastically supplied in a perfect labor market. Total labor endowment and wages in Home are normalized to one. Varieties used for final consumption are partitioned into nests in equilibrium, and consumer demand is in (3).

There is a continuum of sectors $S \in [0, 1]$. Sector S is endowed with three finite sets of firms: A set of downstream Foreign firms $\mathcal{G}_{FS}$, a set of downstream Home firms $\mathcal{G}_{HS}$, and a set of upstream Home firms $\mathcal{U}_S$. Each foreign firm $i \in \mathcal{G}_{FS}$ chooses to exit or to produce a variety in the less-differentiated downstream nest of its sector $\mathcal{L}_S$. If it produces, its fixed cost is $w^* f_L^*$ and a unit cost $c_{iL} = w^* c_{iL}^*$.

To serve the Home market, all Home firms in $\mathcal{G}_S \cup \mathcal{U}_S$ choose among (i) exiting, (ii) producing a less-differentiated variety, and (iii) producing a differentiated variety. Whether firm i is in set $\mathcal{G}_S$ or $\mathcal{U}_S$, if it chooses differentiation, then it produces a variety for final consumption, and it is a monopolist in its own nest. Its fixed cost is f_D and its unit cost is c_{iD}, both in units of labor. Its operating profit is in (8).

[29]The quality literature provides evidence that the production of low-quality goods use intensively low-quality inputs. See Kugler and Verhoogen (2011), Manova and Zhang (2012), Eslava et al. (2015).

Less-differentiated domestic downstream firms combine material inputs from less-differentiated upstream firms with labor. A bundle of inputs costs

$$\tilde{c}_{US} = \left(p_{US}^{1-\eta_U} + 1\right)^{1/(1-\eta_U)}$$
$$\text{where} \quad p_{US} = \left(\sum_{i \in \mathcal{L}_{US}} p_i^{1-\sigma_U}\right)^{1/(1-\sigma_U)} \tag{20}$$

where $\mathcal{L}_{US} \subset \mathcal{U}_S$ is the set of less-differentiated upstream firms, σ_U and η_U satisfy $\sigma_U > \eta_U > 1$. The unit cost of a less-differentiated downstream variety $i \in \mathcal{L}_{HS}$ is $c_{iL} = \tilde{c}_{US}/\phi_i$ where ϕ_i is a firm-specific productivity parameter. An upstream firm $i \in \mathcal{L}_{US}$ has a fixed cost f_U and unit cost c_{iU}, both in terms of labor. The sales of inputs to domestic less-differentiated downstream firms is its only source of revenue.

We uphold the previous assumptions on continuity and lower bound of cost parameters c_{iL}^* for $i \in \mathcal{G}_{FS}$, and c_{iU} for $i \in \mathcal{U}_S$, and c_{iD} for $i \in \mathcal{U}_S \cup \mathcal{G}_{HS}$. Productivity vectors $\{\phi_i\}_{i \in S}$ are bounded and continuous in S almost everywhere.

Sectoral Game with Input Suppliers Firms in sector S play a strategic game with the following stages. (1) In ascending order of cost c_{iU}, Home upstream firms in $\mathcal{U}_S$ make their discrete choices. (2) In ascending order of costs c_{iL}^* Foreign firms in S^* make their discrete choices. (3) In descending order of productivity ϕ_i, Home downstream firms in $\mathcal{G}_S$ make their discrete choices. (4) All firms set prices simultaneously.

The ordering of stages 1, 2, and 3 do not matter for the results below. Unlike Section 4, we separate Home from Foreign downstream firms only because the unit cost of Home firms c_{iL} is set in stage 4. We again consider the subgame perfect equilibrium.

Start with the pricing stage, after all nests are set. Since downstream firms best respond to prices of upstream, they take $\tilde{c}_{US}$ and unit costs $c_{iL} = \tilde{c}_{US}/\phi_i$ for all $i \in \mathcal{L}_{HS}$ as given. Then, the price and operating profit of firms in $\mathcal{L}_S$ are in (7) and (9).

Total spending on inputs by a firm $i \in \mathcal{L}_{HS}$ is

$$\overline{P}^{\eta-1} y P_L^{\sigma-\eta} p_i^{-\sigma} \tilde{c}_{US}/\phi_i$$

Of this spending, the share that goes to an input provider in $\mathcal{L}_{US}$ with price p is

$$\left(\frac{p_{US}}{\tilde{c}_{US}}\right)^{1-\eta_U} \left(\frac{p}{p_{US}}\right)^{1-\sigma_U}$$

Combining these expressions and adding over $i \in \mathcal{L}_{HS}$, the operating profit of a less-differentiated input provider with cost c is

$$\max_p \overline{P}^{\eta-1} y P_L^{\sigma-\eta} \left(\sum_{i\in\mathcal{L}_{HS}} p_i^{-\sigma}/\phi_i\right) (\tilde{c}_{US})^{\eta_U} (p_{US})^{\sigma_U-\eta_U} p^{-\sigma_U} (p-c) \tag{21}$$

The firm internalizes its effect on p_{US} and $\tilde{c}_{US}$ in (20). From the first order conditions, the firm sets price $p = \epsilon_U/(\epsilon_U - 1)$ where ϵ_U is the endogenous elasticity of demand:

$$\epsilon_U = \sigma_U(1-s) + \eta_U s(1-s_{US}) \tag{22}$$

$$\text{where} \quad s_{US} = \left(\frac{p_{US}}{\tilde{c}_{US}}\right)^{1-\eta_U}$$

$$s = \left(\frac{p}{p_{US}}\right)^{1-\sigma_U}$$

s_{US} is the share of material inputs in the cost of domestic less-differentiated downstream firms, and s is the share of the firm in the sales of these material inputs. Elasticity ϵ_U is again a weighted average of elasticities. If the firm's share s is small, its elasticity is close to σ_U the elasticity of substitution among varieties in $\mathcal{L}_{US}$. If share s is large, then it competes with labor with an elasticity η_U. The term $(1 - s_{US})$ appears because upstream firms take as given the price and sales of downstream firms. So, with a share ss_{US} it faces an elasticity zero. Assume that, for all sectors S and all $i \in \mathcal{U}_S$, cost c_{iU} is sufficiently high that the elasticity $\epsilon_U > \eta$ whenever $s = 1$. This assumption ensures that the firm's problem has a solution and that its markup increases with differentiation.[30]

Equation (22) implicitly defines the vector of prices in nest $\mathcal{L}_{US}$ given costs c_{iU} for all $i \in \mathcal{L}_{US}$. The operating profit of firm $i \in \mathcal{L}_{US}$ is

$$\pi_U(c_{iU}, \mathbf{c}_{-iU}, \phi_S, \mathbf{c}^*_{LS}) = \overline{P}^{\eta-1} y P_L^{\sigma-\eta} \left(\sum_{i' \in \mathcal{L}_{HS}} p_{i'}^{-\sigma}/\phi_{i'} \right) (\tilde{c}_{US})^{\eta_U} (p_{US})^{\sigma_U - \eta_U} \left(\frac{\epsilon_U c_{iU}}{\epsilon_U - 1} \right)^{-\sigma_U}$$

where $\mathbf{c}_{-iU}$ is the vector of its competitors' costs. We omit the arguments of functions on the right-hand side. Elasticity ϵ_U and price indices $\tilde{c}_{US}$ and p_{US} are functions of $(c_{iU}, \mathbf{c}_{-iU})$. The price p_i of downstream firms $i \in \mathcal{L}_{HS}$ and P_L are functions of $(\tilde{c}_U(\{c_{iU}, \mathbf{c}_{-iU}\})/\phi_S, w^* \mathbf{c}^*_{LS})$, where $\phi_S = \{\phi_i\}_{i \in \mathcal{L}_{HS}}$, $\mathbf{c}^*_{LS} = \{c^*_{iL}\}_{i \in \mathcal{L}_{FS}}$, and $\tilde{c}_U(\mathbf{c}_U)$ is the cost of input bundle $\tilde{c}_{US}$ in (20) when the vector of unit costs in $\mathcal{L}_{US}$ is $\mathbf{c}_U = \{c_{iU}\}_{i \in \mathcal{L}_{US}}$.

Given payoffs, the equilibrium discrete choices are solved by backward induction as in Sections 3 and 4. Each firm effectively chooses among subgames when making its discrete choice, and the equilibrium is unique up to a perturbation of parameters.

Because upstream firms move first, there may be strategic complementarities among them. A firm may enter $\mathcal{L}_{US}$ only in subgames with a sufficiently large set of competitors in $\mathcal{L}_{US}$ to drive down equilibrium cost $\tilde{c}_{US}$ and induce downstream entry.

Exporting by Home Firms A downstream Home firm $i \in \mathcal{G}_{HS}$ in any sector S may export to Foreign at a fixed cost f^* and a unit cost $1/\phi_i$. We assume that these costs use only labor, not upstream inputs from $\mathcal{L}_{US}$, to isolate shocks to import competition from shocks to exporting. The firm's sales and net profits from exporting are

$$\begin{aligned} X^*(\phi_i, w^*) &= (\phi_i w^*)^{\sigma-1} w^* Y^*, \\ \pi^*(\phi_i, w^*) &= \frac{X^*(\phi_i, w^*)}{\sigma} - f^* \end{aligned} \tag{23}$$

[30]Since the lower bound on a firm's price is c_{iU} a sufficient condition is for $\eta < \eta_U$ and all $c_{iU} > \underline{c}_U$ where $\underline{c}_U > 0$ satisfies $\eta_U[1 - (\underline{c}_U^{1-\eta_U}/(1 + \underline{c}_U^{1-\eta_U}))] > \eta$.

where $Y^* > 0$ is a parameter. The firm exports if and only if $\phi_i \geq \phi^*(w^*)$, where

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

Equilibrium of Model with Inputs Firms in all sectors play their subgame equilibrium strategies given income, price index, and foreign wages $(y, \overline{P}, w^*)$. Price index $\overline{P}$ is in (10). Income is

$$y = 1 + \int_0^1 \Bigg[\sum_{\{i \in \mathcal{G}_{HS}: \phi_i > \phi^*(w^*)\}} \pi^*(\phi_i, w^*) + \sum_{i \in \mathcal{L}_{US}} \pi_U(c_{iU}, \mathbf{c}_{-iU}, \phi_S, \mathbf{c}^*_{LS}) + \sum_{i \in \mathcal{D}_S} \pi_D(c_{iD}) + \sum_{i \in \mathcal{L}_{HS}} \pi_L(c_{iU}, \mathbf{c}_{-iU}, \phi_S, \mathbf{c}^*_{LS}) \Bigg] dS. \tag{24}$$

Trade balances when

$$\int_0^1 \sum_{\{i \in \mathcal{G}_{HS}: \phi_i > \phi^*(w^*)\}} X^*(\phi_i, w^*) dS = \overline{P}^{\eta-1} y \int_0^1 \sum_{i \in \mathcal{L}_{FS}} P_L(\mathbf{c}_{LS})^{\sigma-\eta} \left(\frac{w^* c^*_{iL} \epsilon_L(w^* c^*_{iL}, \mathbf{c}_{-iL})}{\epsilon_L(w^* c^*_{iL}, \mathbf{c}_{-iL}) - 1} \right)^{1-\sigma} dS. \tag{25}$$

An equilibrium with input suppliers is a set of firm strategies and a vector $(y, \overline{P}, w^*)$ such that firm strategies are subgame perfect and equations (10), (24), and (25) hold.

6.3 Results of Model with Input Suppliers

A large decrease in the cost parameters of foreign firms c^*_{iL} for all $i \in \mathcal{G}_{FS}$ in some sector S has the same effect on Home downstream firms $i \in \mathcal{G}_S$ as in Section 4. It increases exit and differentiation. The markup increases for firms that move from less-differentiation to differentiation, and it decreases for firms that remain less-differentiated. Among upstream firms $i \in \mathcal{U}_S$, the shock increases exit, differentiation, and markups.

The cost the bundle of inputs $\tilde{c}_{US}$ is bounded below by the cost when all upstream firms

$i \in \mathcal{U}_S$ decides less-differentiation. Then, it is always possible to decrease c^*_{iL} sufficiently for P_{-iL} to decrease for all domestic firms i relative to the firm's unit cost when the input bundle is at its lower bounded. Such a decrease in c^*_{iL} decreases the markup, and the profit from less-differentiation for all domestic downstream firms as in Section 4.

The exit, differentiation and drop in sales of Home firms in $\mathcal{L}_S$ all decrease the sales of less-differentiated inputs. These sales go to zero as c^*_{iL} goes to zero. So, it is always possible to construct a sufficiently large shock to induce exit and differentiation among upstream firms. But the elasticity of demand in (22) depends on market share, not on total sales. Since we have just proved that set $\mathcal{L}_{US}$ decreases, then market shares s and $s_{US}s$ both increase. So, the markup of upstream firms that remain less-differentiated increases. By assumption, the markup of firms that differentiate also increase.

In sum, the sales of less-differentiated varieties decreases for both upstream and downstream Home firms, prompting these firms to exit or differentiate. But market shares, which govern markups, decrease only for downstream firms directly competing with exports. The opposing effects of the shock on the markups of upstream and downstream firms is consistent with Table 3, where tariff cuts are associated with larger increases in the productivity of input suppliers (downstream tariffs) than in the productivity of import-competing firms (output tariffs).

7 Robustness and Extensions of Empirical Results

Detailed procedures and tables are in Appendix A. Tables A.11, A.12, and A.13 presents robustness checks for Tables 1 and 3. The dependent variable is revenue TFP in Table A.11, measures of the introduction of new goods in Table A.12, and the ranking of sectoral skill intensity in Table A.13. In each table, row 1 presents the results with all firms, including multinationals and SOE's. Rows 2 and 3 check whether collinearity between output and downstream tariffs affect the results in Table 3, by dropping one tariff measure at a time. To check for selection, row 5 uses only a balanced panel of firms that survived in all ten years of data. The number of observations decreases from 1,037,738 to 65,809. Row 6 follow Wooldridge (2010) in estimating a selection equation using a probit, and then including the estimated Mills ratio in the main specification. We use the accounting profit share of the firm in the previous period as the selection variable in the probit excluded from the main specification. Row 7 excludes textiles and apparel, which were affected by the expiration of the multifiber agreement (MFA) in the period of our data. Row 8 excludes computers and peripherals, which experienced a large growth in offshoring.

The negative coefficients on output tariffs of Table 1 are mostly robust to these tests. When the panel is balanced and the dependent variable is the share of new goods in trade, the coefficient loses statistical significance. Firms that survive through the ten years or our sample are more likely to have introduced successful products that hold a large share of sales. Reassuringly the negative coefficients are significant in all IV specifications when we include only non-exporters, the firms for which we expect the results to be strongest.

In presenting Table 3, we highlighted that the coefficient on downstream tariffs is about seven to eight times larger (in magnitude) than the coefficient on output tariffs in our preferred specification, the IV with only non-exporters, when the dependent variable is revenue TFP. This result holds in all robustness checks above. In contrast and also in line with Table 3, the coefficient on downstream tariffs is generally negative but it is less robust than the coefficient on output tariffs when the dependent variable measures the introduction of new goods or sectoral skill intensity. This result suggest that input suppliers also differentiate their products but to a less extent than firms directly competing with imports.

Tables A.14, A.15, and A.16 repeat these robustness checks for the regressions with the interaction of quartile of sales with tariffs in Table 2. We highlighted two messages in Table 2. First, the output tariffs coefficient is smaller (more negative) in smallest quartiles of sales relative to the larger quartiles in the TFP regressions. Like Table 2, this result only holds in the OLS. On the regressions of new goods and sectoral skill intensity, there is no systematic differences across quartiles of sales. Second, the coefficient on output tariffs interacted with the smallest quartile of sales is negative for all dependent variables, revenue TFP, the introduction of new goods or sectoral skill intensity. This second result is robust in all Tables A.14, A.15, and A.16. It is relevant because it only arises in the model if the fixed cost to differentiate is small, which in turn is the condition for large and widespread decreases in foreign costs to increase differentiation overall (not just in some sectors relative to others).

8 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 stylized extension of Atkeson and Burstein (2008), in which import-competing firms escape foreign competition by specializing in new market niches (nests). Since these product-differentiation strategies to escape import competition improve welfare in the model, they provide a rationale for policy makers' view.

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. These opposing effects may explain the mixed evidence in the literature relating tariff cuts to firm productivity. We circumvent this difficulty using data on new goods and sectoral skill intensity which are comparable across time even in periods of large changes in demand, technologies and output, such as trade liberalization episodes.

Our proposed mechanism may be relevant in other contexts. Firms escaping competition in established market segments innovate and spur economic growth. Fort et al. (2018) associate import penetration in the United States to shifts of manufacturing firms to the service sector, suggesting that coupling products with services may accelerate structural change.[31] Differentiation may also factor in a multinational's decision to serve a foreign market through exports or an affiliate, which may be better positioned to offer non-tradable services and greater customization.

References

Ackerberg, D. A., K. Caves, and G. Frazer (2015). Identification properties of recent production function estimators. *Econometrica 83*(6), 2411–2451.

Aghion, P., N. Bloom, R. Blundell, R. Griffith, and P. Howitt (2005). Competition and innovation: An inverted-u relationship. *The Quarterly Journal of Economics 120*(2), 701–728.

Aghion, P., J. Cai, M. Dewatripont, L. Du, A. Harrison, and P. Legros (2015). Industrial policy and competition. *American Economic Journal: Macroeconomics 7*(4), 1–32.

Amiti, M., O. Itskhoki, and J. Konings (2014). Importers, exporters, and exchange rate disconnect. *American Economic Review 104*(7), 1942–78.

Amiti, M. and J. Konings (2007). Trade intermediate and productivity: Liberalization, inputs, from indonesia evidence. *The American Economic Review 97*(5), 1611–1638.

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012). New trade models, same old gains? *American Economic Review 102*(1), 94–130.

Atkeson, A. and A. Burstein (2008). Pricing-to-market, trade costs, and international relative prices. *The American Economic Review 98*(5), 1998–2031.

Attanasio, O., P. K. Goldberg, and N. Pavcnik (2004). Trade reforms and wage inequality in colombia. *Journal of Development Economics 74*(2), 331–366.

[31] See Cravino and Sotelo (Cravino and Sotelo) for other effects of trade on structural change.

Bernard, A. B., J. Eaton, J. B. Jensen, and S. Kortum (2003a). Plants and productivity in international trade. *American economic review 93*(4), 1268–1290.

Bernard, A. B., J. Eaton, J. B. Jensen, and S. S. Kortum (2003b). Plants and productivity in international trade. *American Economic Review 93*(4), 1268–1290.

Bernard, A. B., S. J. Redding, and P. K. Schott (2011). Multiproduct firms and trade liberalization. *The Quarterly Journal of Economics 126*(3), 1271–1318.

Blalock, G. and P. J. Gertler (2008). Welfare gains from foreign direct investment through technology transfer to local suppliers. *Journal of International Economics 74*(2), 402–421.

Bøler, E. A. (2019). Technology-skill complementarity in a globalized world. CEPR `http://www.estherboler.com/files/boler_jmp.pdf`.

Boyd, G., N. Abhijeet, C. Richter, and S. Laprise (2008). Asian automakers: Sector outlook. *CLSA Report*.

Brandt, L. and E. Thun (2010). The fight for the middle: upgrading, competition, and industrial development in china. *World Development 38*(11), 1555–1574.

Brandt, L. and E. Thun (2016). Constructing a ladder for growth: policy, markets, and industrial upgrading in china. *World Development 80*, 78–95.

Brandt, L., J. Van Biesebroeck, L. Wang, and Y. Zhang (2017). Wto accession and performance of chinese manufacturing firms. *American Economic Review 107*(9), 2784–2820.

Broda, C. and D. E. Weinstein (2006). Globalization and the gains from variety. *The Quarterly Journal of Economics 121*(2), 541–585.

Burstein, A., J. Cravino, and J. Vogel (2016). Importing skill-bias technology. *American Economic Journal: Macroeconomics 5*(2), 32–71.

Burstein, A. and J. Vogel (2016). International trade, technology, and the skill premium. forthcoming.

Bustos, P. (2011). Trade liberalization, exports and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *The American Economic Review 101*(1), 304–340.

Caliendo, L. and E. Rossi-Hansberg (2012). The impact of trade on organization and productivity. *The Quarterly Journal of Economics 127*(3), 1393–1467.

Chen, C. and C. Steinwender (2019). Import competition, heterogeneous preferences of managers, and productivity. NBER Working Paper, No w25539.

Cravino, J. and S. Sotelo. Trade induced structural change and the skill premium. *American Economic Journal: Macroeconomics*.

De Loecker, J. (2007). Do exports generate higher productivity? evidence from slovenia. *Journal of international economics 73*(1), 69–98.

De Loecker, J. and F. Warzynski (2012). Markups and firm-level export status. *The American Economic Review 102*(6), 2437–2471.

DeLoecker, J., P. K. Goldberg, A. Khandelwal, and N. Pavcnik (2016). Prices, markups and trade reform. *Econometrica 84*(2), 445–510.

Dhingra, S. (2013). Trading away wide brands for cheap brands. *American Economic Review 103*(6), 2554–84.

Dhingra, S. and J. Morrow (2018). Monopolistic competition and optimum product diversity under firm heterogeneity. *Journal of Political Economy*.

Dixit, A. K. and J. E. Stiglitz (1977). Monopolistic competition and optimum product diversity. *The American Economic Review 67*(3), 297–308.

Du, L., A. Harrison, and G. H. Jefferson (2012). Testing for horizontal and vertical foreign investment spillovers in china, 1998–2007. *Journal of Asian Economics 23*(3), 234–243.

Edmond, C., V. Midrigan, and D. Y. Xu (2015). Competition, markups, and the gains from international trade. *The American Economic Review 105*(10), 3183–3221.

Eslava, M., A. C. Fieler, and D. Y. Xu (2015). (indirect) input linkages. *The American Economic Review Papers and Proceedings 105*(5), 662–666.

Eslava, M., J. Haltiwanger, A. Kugler, and M. Kugler (2013). Trade and market selection: Evidence from manufacturing plants in colombia. *Review of Economic Dynamics 16*(1), 135–158.

Farhoomand, A. and M. Schuetz (2007). Chery automobile company: Evolution of the chinese automotive industry. *Asia Case Research Center at the University of Hong Kong HKU676*.

Feenstra, R. C. and G. H. Hanson (1997). Foreign direct investment and relative wages: Evidence from mexico's maquiladoras. *Journal of International Economics 42*(3), 371–393.

Feng, D. and X. Wei (2015). Haier electronics. *CLSA Report*.

Fieler, A. C., M. Eslava, and D. Y. Xu (2018). Trade, quality upgrading, and input linkages: Theory and evidence from colombia. *The American Economic Review 108*(1), 109–46.

Fort, T. C., J. R. Pierce, and P. K. Schott (2018). New perspectives on the decline of us manufacturing employment. *Journal of Economic Perspectives 32*(2), 47–72.

Foster, L., J. Haltiwanger, and C. Syverson (2008). Reallocation, firm turnover, and efficiency: Selection on productivity or profitability? *American Economic Review 98*(1), 394–425.

Gandhi, A., S. Navarro, D. Rivers, et al. (2017). How heterogeneous is productivity? a comparison of gross output and value added. *Journal of Political Economy*.

Goldberg, P. K., A. K. Khandelwal, N. Pavcnik, and P. Topalova (2009). Trade liberalization and new imported inputs. *The American Economic Review, Papers and Proceedings 99*(2), 494–500.

Harrigan, J., A. Reshef, and F. Toubal (2019). Techies, trade, and skill-biased productivity. Paris School of Economics `http://www.parisschoolofeconomics.com/reshef-ariell/papers/HRT_productivity_nov18.pdf`.

Harrison, A. E. (1994). Productivity, imperfect competition and trade reform: Theory and evidence. *Journal of international Economics 36*(1-2), 53–73.

Helpman, E., O. Itskhoki, M.-A. Muendler, and S. J. Redding (2017). Trade and inequality: From theory to estimation. *The Review of Economic Studies 84*(1), 357–405.

Holmes, T. J. and J. A. Schmitz (2010). Competition and productivity: A review of evidence. *Annual Review of Economics 2*(1), 619–642.

Holmes, T. J. and J. J. Stevens (2014). An alternative theory of the plant size distribution, with geography and intra-and international trade. *Journal of Political Economy 122*(2), 369–421.

Impullitti, G. and O. Licandro (2017). Trade, firm selection and innovation: The competition channel. *The Economic Journal 128*(608), 189–229.

Javorcik, B. S. (2004). Does foreign direct investment increase the productivity of domestic firms? in search of spillovers through backward linkages. *The American Economic Review 94*(3), 605–627.

Kee, H. L. and H. Tang (2016). Domestic value added in exports: Theory and firm evidence from china. *The American Economic Review 106*, 1402–1436.

Kugler, M. and E. Verhoogen (2011). Prices, plants and product quality. *Review of Economic Studies 79*(1), 307–339.

Lee, E. (2018). Trade, inequality, and the endogenous sorting of heterogeneous workers. https://www.dropbox.com/s/t0ygwauqmeu61lr/Lee_JMP_latest.pdf?dl=0.

Lileeva, A. and D. Trefler (2010). Improved access to foreign markets raises plant-level productivity...for some plants. *The Quarterly Journal of Economics 125*(3), 1051–1099.

Linarello, A. (2018). Direct and indirect effects of trade liberalization: Evidence from chile. *Journal of Development Economics 134*, 160–175.

Manova, K. and Z. Zhang (2012). Export prices across firms and destinations. *The Quarterly Journal of Economics 127*(1), 379–436.

Mayer, T., M. J. Melitz, and G. I. Ottaviano (2014). Market size, competition, and the product mix of exporters. *American Economic Review 104*(2), 495–536.

Melitz, M. J. and G. I. Ottaviano (2008). Market size, trade, and productivity. *The review of economic studies 75*(1), 295–316.

Olley, G. S. and A. Pakes (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica 64*(6), 1263–1297.

Rose, G. (2015). Special entrepreneurship issue: Here come the disruptors. *Foreign Affairs 94*(1).

Spence, M. (1976a). Product differentiation and welfare. *The American Economic Review 66*(2), 407–414.

Spence, M. (1976b). Product selection, fixed costs, and monopolistic competition. *The Review of economic studies 43*(2), 217–235.

Teagarden, M. B. and C. Fifi (2015). Xiaomi, inc.: The rise of a chinese indigenous competitor. *Thunderbird School of Global Management TB0417*.

Tintelnot, F., A. K. Kikkawa, M. Mogstad, and E. Dhyne (2018). Trade and domestic production networks. *working paper*.

Tybout, J. R. (2003). Plant- and firm-level evidence on the 'new' trade theories. In E. K. Choi and J. Harrigan (Eds.), *Handbook of International Trade*. Blackwell Publishing Ltd.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Yeaple, S. R. (2005). A simple model of firm heterogeneity, international trade, and wages. *Journal of International Economics 65*(1), 1–20.

Escaping import competition and Downstream Tariffs in China

Appendix

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Contents

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A Additional Empirical Results

This Appendix presents additional empirical results. The main text shows only the variables of interest. Appendix A.1 details the construction of control variables and reports their coefficients for the regressions in the main text. Appendix A.2 studies other firm outcomes such as exit, sector switching, and sales. Appendix A.3 checks the robustness of main results.

A.1 Control Variables

A.1.1 Definition of Control Variables

In addition to the tariff measures below, 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 Javorkic (2004). 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. 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 Javorcik (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).

We construct three measures of tariffs that China imposes on its imports. *Output_tariff*$_{jt}$ is the tariff on sector j at time t. *Upstream_tariff*$_{jt}$ are tariffs at time t on the sectors that provide inputs to sector j (referred to as input tariffs in the literature). *Downstream_tariff*$_{jt}$ are tariffs on the sectors to which firms in sector j provide inputs.

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

To measure tariffs on sectors upstream and downstream from each firm's own sector, we use the 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. We create a concordance between the tariff data, the input-output table, and the survey data, and we end up with 71 sectors.

Following the literature, the upstream tariff is a weighted average of output tariffs:[1]

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

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

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

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

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

A.1.2 Coefficients on Control Variables

Tables in the main text report only the coefficients of interest, and here we report the coefficients on all control variables. Tables A.1, A.2, and A.3 refer to the basic regressions with the three measures of tariffs as the coefficients of interest. Tables A.4, A.5, and A.6 refer to the regressions where the dependent variable output_tariff is substituted with the interaction between output_tariff and indicator variables of whether the firm is in each of the four quartiles of firm sales.

Table A.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 $p < 0.1$.

Table A.2: Introduction of New Goods

	All enterprises, excluding SOEs and Multinationals				Only Non-Exporters	
dependent variable →	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 A.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.

Table A.4: Regressions of Productivity on Tariffs Interacted with Lagged Quartile of Sales

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

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
	OP	FE	OP	FE	OP	FE
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff*q1	-0.0337***	-0.0344***	-0.0334**	-0.0276	-0.0435***	-0.0365**
	(0.00341)	(0.00350)	(0.0169)	(0.0175)	(0.0167)	(0.0172)
output_tariff*q2	-0.0302***	-0.0312***	-0.0277	-0.0249	-0.0396**	-0.0353*
	(0.00313)	(0.00322)	(0.0179)	(0.0189)	(0.0173)	(0.0181)
output_tariff*q3	-0.0261***	-0.0273***	-0.00859	-0.00510	-0.0180	-0.0132
	(0.00314)	(0.00324)	(0.0190)	(0.0198)	(0.0189)	(0.0196)
output_tariff*q4 (largest)	-0.0240***	-0.0253***	-0.0129	-0.0118	-0.0259	-0.0233
	(0.00327)	(0.00340)	(0.0168)	(0.0178)	(0.0173)	(0.0182)
downstream_tariff	-0.0112*	-0.0117	-0.153**	-0.156**	-0.388***	-0.404***
	(0.00639)	(0.00719)	(0.0643)	(0.0645)	(0.0714)	(0.0732)
upsrteam_tariff	-0.137***	-0.146***	-0.445***	-0.521***	-0.322***	-0.389***
	(0.0124)	(0.0133)	(0.0988)	(0.101)	(0.0965)	(0.0984)
index_subsidy	0.00466***	0.00617***	0.00401***	0.00540***	0.00206	0.00288*
	(0.00129)	(0.00130)	(0.00130)	(0.00132)	(0.00170)	(0.00171)
index_tax	0.0188***	0.0192***	0.0186***	0.0189***	0.0180***	0.0185***
	(0.000989)	(0.000995)	(0.00100)	(0.00101)	(0.00105)	(0.00106)
index_interest	-0.00623***	-0.00718***	-0.00624***	-0.00720***	-0.00684***	-0.00773***
	(0.000960)	(0.000967)	(0.000972)	(0.000981)	(0.00112)	(0.00114)
Export_share	0.190***	0.223***	0.450***	0.513***	0.567***	0.632***
	(0.0343)	(0.0354)	(0.0545)	(0.0569)	(0.0601)	(0.0635)
State_share	-0.00327	-0.00319	-0.00325	-0.00313	-0.000174	0.000417
	(0.00440)	(0.00435)	(0.00443)	(0.00439)	(0.00490)	(0.00486)
Horizontal FDI	0.192***	0.239***	0.177***	0.218***	0.282***	0.333***
	(0.0424)	(0.0447)	(0.0457)	(0.0480)	(0.0541)	(0.0563)
Downstream FDI	0.812***	0.706***	1.599***	1.543***	2.215***	2.171***
	(0.197)	(0.204)	(0.321)	(0.329)	(0.354)	(0.367)
Upstream FDI	0.0527	0.0560	0.190**	0.213**	0.0287	0.0504
	(0.0816)	(0.0824)	(0.0901)	(0.0911)	(0.0927)	(0.0937)
q1	-0.0804***	-0.0909***	-0.0560**	-0.0756***	-0.0613**	-0.0801**
	(0.00729)	(0.00766)	(0.0275)	(0.0279)	(0.0308)	(0.0313)
q2	-0.0660***	-0.0738***	-0.0465**	-0.0573**	-0.0479*	-0.0584**
	(0.00626)	(0.00657)	(0.0236)	(0.0238)	(0.0267)	(0.0269)
q3	-0.0435***	-0.0482***	-0.0587**	-0.0684**	-0.0645**	-0.0732**
	(0.00509)	(0.00524)	(0.0269)	(0.0271)	(0.0314)	(0.0316)
Observations	701,765	701,765	701,765	701,765	548,283	548,283

output_tariff*q# indicates output tariffs interacted with a dummy for whether sales is in the first, second, third or fourth quartile of sales in the lagged year. 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 $p < 0.1$.

Table A.5: Introduction of New Goods on Tariffs Interacted with Lagged Quartile of Sales

	All Enterprises excluding SOE's and multinationals				Only Non-Exporting Enterprises	
dependent variable →	new product share	0-1 dummy for introducing a new product	new product share	0-1 dummy for introducing a new product	new product share	0-1 dummy for introducing a new product
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(6)	(5)
output_tariff*q1	0.000531	-0.00138	-0.0152**	-0.0513***	-0.0123**	-0.0327***
	(0.00144)	(0.00348)	(0.00746)	(0.0184)	(0.00582)	(0.0124)
output_tariff*q2	0.000509	0.000862	-0.0169**	-0.0337*	-0.0117**	-0.0252**
	(0.00142)	(0.00328)	(0.00747)	(0.0177)	(0.00575)	(0.0120)
output_tariff*q3	0.000192	0.00117	-0.0148*	-0.0293	-0.00981	-0.0168
	(0.00153)	(0.00343)	(0.00786)	(0.0191)	(0.00612)	(0.0134)
output_tariff*q4 (largest)	-0.000867	-0.00185	-0.0189**	-0.0264	-0.0131**	-0.0290**
	(0.00179)	(0.00377)	(0.00834)	(0.0194)	(0.00628)	(0.0135)
downstream_tariff	-0.00253	0.0142	-0.0381*	-0.0742	-0.0500***	-0.0725**
	(0.00238)	(0.00909)	(0.0224)	(0.0497)	(0.0177)	(0.0351)
upsrteam_tariff	0.00138	-0.00309	0.0440	0.137*	0.0469**	0.113**
	(0.00403)	(0.0103)	(0.0313)	(0.0710)	(0.0231)	(0.0472)
index_subsidy	0.00544***	0.0138***	0.00547***	0.0140***	0.00417***	0.0100***
	(0.000851)	(0.00171)	(0.000845)	(0.00170)	(0.000885)	(0.00163)
index_tax	-0.000130	-0.00176	-9.29e-05	-0.00166	0.000277	-0.000624
	(0.000424)	(0.00108)	(0.000429)	(0.00109)	(0.000421)	(0.000861)
index_interest	-0.00249***	-0.00776***	-0.00242***	-0.00763***	-0.00135***	-0.00462***
	(0.000514)	(0.00126)	(0.000512)	(0.00126)	(0.000496)	(0.000970)
Export_share	-0.0112	-0.0153	0.0107	0.0223	0.00664	-0.0147
	(0.00984)	(0.0262)	(0.0143)	(0.0337)	(0.0129)	(0.0277)
State_share	-0.00205	0.00188	-0.00207	0.00185	-0.00335	-0.00108
	(0.00247)	(0.00471)	(0.00247)	(0.00473)	(0.00255)	(0.00473)
Horizontal FDI	0.0173	0.0158	0.00538	-0.0249	0.0164	0.0125
	(0.0113)	(0.0310)	(0.0150)	(0.0392)	(0.0123)	(0.0261)
Downstream FDI	-0.0245	-0.0637	0.0334	0.0637	0.0722*	0.0682
	(0.0277)	(0.0695)	(0.0498)	(0.111)	(0.0401)	(0.0789)
Upstream FDI	-0.00302	-0.0118	-0.0283**	-0.0606**	-0.0309***	-0.0550**
	(0.00727)	(0.0151)	(0.0127)	(0.0281)	(0.0110)	(0.0221)
q1	-0.00757*	-0.0104	-0.0129	0.0480*	-0.00451	-0.00260
	(0.00400)	(0.00893)	(0.0123)	(0.0270)	(0.0115)	(0.0239)
q2	-0.00851**	-0.0186**	-0.00984	0.00450	-0.00623	-0.0196
	(0.00375)	(0.00789)	(0.0112)	(0.0247)	(0.0113)	(0.0222)
q3	-0.00704**	-0.0187***	-0.0139	-0.00515	-0.00938	-0.0350
	(0.00337)	(0.00648)	(0.0127)	(0.0284)	(0.0125)	(0.0258)
Observations	701,765	701,765	701,765	701,765	548,283	548,283

output_tariff*q# indicates output tariffs interacted with a dummy for whether sales is in the first, second, third or fourth quartile of sales in the lagged year. 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 A.6: Sectoral skill intensity and tariffs interacted with lagged quartiles of firm sales

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*q1	-17.70***	-21.31***	-18.51***	-15.49***
	(1.067)	(3.914)	(1.012)	(3.441)
output_tariff*q2	-17.62***	-19.51***	-18.32***	-13.33***
	(1.070)	(3.662)	(1.015)	(3.283)
output_tariff*q3	-17.41***	-20.63***	-18.07***	-15.17***
	(1.079)	(3.835)	(1.011)	(3.446)
output_tariff*q4 (largest)	-16.95***	-23.32***	-17.89***	-17.71***
	(1.105)	(3.890)	(1.078)	(3.499)
downstream_tariff	5.040***	-40.18***	4.296***	-42.09***
	(1.297)	(8.168)	(1.250)	(8.872)
upsrteam_tariff	33.69***	110.0***	35.25***	94.50***
	(3.102)	(14.99)	(3.153)	(14.23)
index_subsidy	0.557***	0.575***	0.721***	0.694***
	(0.186)	(0.199)	(0.226)	(0.239)
index_tax	0.120	0.136	0.202*	0.142
	(0.106)	(0.112)	(0.120)	(0.125)
index_interest	-0.327***	-0.276**	-0.341**	-0.347**
	(0.126)	(0.132)	(0.144)	(0.149)
exportshare_sector	-189.8***	-181.7***	-206.3***	-198.1***
	(9.236)	(8.140)	(8.927)	(9.022)
State_share	-0.147	0.287	-0.311	0.104
	(0.526)	(0.529)	(0.594)	(0.600)
Horizontal FDI	65.14***	40.52***	71.19***	52.45***
	(8.281)	(10.34)	(8.537)	(10.07)
Downstream FDI	541.6***	606.0***	549.6***	611.8***
	(26.71)	(30.71)	(29.73)	(34.02)
Upstream FDI	-33.28***	-42.72***	-42.68***	-49.50***
	(6.264)	(7.028)	(6.869)	(7.850)
q1	2.157	-4.534	2.022	-4.695
	(1.333)	(4.008)	(1.467)	(4.343)
q2	1.803	-8.723**	1.407	-9.660**
	(1.149)	(3.859)	(1.287)	(4.194)
q3	0.944	-6.313	0.540	-5.658
	(0.911)	(3.935)	(1.033)	(4.189)
Observations	701,765	701,765	548,283	548,283

output_tariff*q# indicates output tariffs interacted with a dummy for whether sales is in the first, second, third or fourth quartile of sales in the lagged year. 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.

A.2 Other Firm Outcomes

We study the relation between tariffs various firm outcomes. Table A.7 runs the main specification with an exit dummy as the dependent variable. The IV results are consistent with the prediction of the model that import-competing firms and their input suppliers are more likely to exit when tariffs fall.

In Table A.8, the dependent variable is a dummy for whether the firm switches sectors. To the extent that product differentiation may be accompanied by sectoral switches, the model predicts the coefficient on downstream and output tariffs should be negative. The coefficient is negative, though statistically insignificant for downstream tariffs.

Table A.9 repeats the main regression specification with revenue as the dependent variable. In all IV specifications, the coefficient on tariff is positive and statistically significant. Tariff cuts are associated with decreases in sales, especially among non-exporting firms. This result is consistent with most international trade models. The results for OLS specifications is more mixed, many of the coefficients are negative and statistically insignificant.

Table A.10 confirms the well-known positive relationship between revenue and TFP in our data. The table shows the coefficients from regressing TFP on revenue with time fixed effects. The coefficient is around 0.20, and it is statistically significant at a 99% confidence level in all specifications, which vary in their TFP measure and in whether they include sector fixed effects. In the model, the increasing relation between firm size and markup holds within sectors among firms that are less-differentiated. Firms that are differentiated have higher markups and generally vary in size.

Table A.7: Determinants of Exit

	All enterprises OLS (1)	Non-Exporters OLS (2)	All enterprises IV (3)	Non-Exporters IV (4)
output_tariff	-0.00153	-0.00257	-0.0640**	-0.0930***
	(0.00249)	(0.00295)	(0.0249)	(0.0229)
downstream_tariff	-0.00412	-0.00311	-0.290***	-0.370***
	(0.00357)	(0.00402)	(0.0700)	(0.0788)
upsrteam_tariff	0.00826	0.0186**	0.290***	0.332***
	(0.00724)	(0.00825)	(0.107)	(0.103)
index_subsidy	-0.0208***	-0.0193***	-0.0207***	-0.0192***
	(0.00129)	(0.00164)	(0.00130)	(0.00165)
index_tax	-0.00440***	-0.00533***	-0.00439***	-0.00569***
	(0.000871)	(0.000976)	(0.000890)	(0.00101)
index_interest	0.0103***	0.00956***	0.0105***	0.00988***
	(0.00104)	(0.00116)	(0.00106)	(0.00119)
exportshare_sector	0.0243	0.00351	0.189***	0.233***
	(0.0160)	(0.0195)	(0.0484)	(0.0547)
State_share	0.00368	0.000947	0.00376	0.000775
	(0.00466)	(0.00533)	(0.00470)	(0.00540)
Horizontal FDI	-0.0618***	-0.0739***	-0.147***	-0.142***
	(0.0206)	(0.0236)	(0.0434)	(0.0411)
Downstream FDI	0.0772	0.0704	0.596***	0.629***
	(0.0487)	(0.0577)	(0.143)	(0.159)
Upstream FDI	-0.00591	0.00403	-0.127***	-0.196***
	(0.0106)	(0.0132)	(0.0349)	(0.0405)
Observations	987,022	785,271	987,022	785,271

Notes: Standard errors are clustered by firm and initial sector. Linear probability where the dependent variable is a zero-one dummy variable for whether or not the establishment exits. All specifications include firm and time effects. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.8: Linear Probability Model of Whether or Not Establishment Switched Sector

	All enterprises OLS (1)	Non-Exporters OLS (2)	All enterprises IV (3)	Non-Exporters IV (4)
output_tariff	-0.00137	-0.000845	-0.0158	-0.0323**
	(0.00149)	(0.00143)	(0.0165)	(0.0150)
downstream_tariff	-0.0108***	-0.0111***	0.0235	0.0277
	(0.00279)	(0.00253)	(0.0381)	(0.0380)
upsrteam_tariff	-0.0132***	-0.0159***	0.0938	0.124*
	(0.00275)	(0.00258)	(0.0736)	(0.0694)
index_subsidy	0.00989***	0.00974***	0.00441***	0.00557***
	(0.000958)	(0.00108)	(0.00108)	(0.00128)
index_tax	-0.00104*	-0.000778	-0.000452	-0.000512
	(0.000584)	(0.000609)	(0.000671)	(0.000737)
index_interest	-0.00330***	-0.00249***	-0.00249***	-0.00194**
	(0.000622)	(0.000630)	(0.000829)	(0.000958)
exportshare_sector	0.00919	0.0169**	-0.192***	-0.176***
	(0.00656)	(0.00669)	(0.0498)	(0.0518)
State_share	-0.0103***	-0.00731***	-0.00131	-0.000320
	(0.00164)	(0.00179)	(0.00288)	(0.00330)
Horizontal FDI	-0.00344	0.00207	-0.103**	-0.167***
	(0.00976)	(0.00915)	(0.0524)	(0.0517)
Downstream FDI	0.157***	0.158***	0.357**	0.362**
	(0.0263)	(0.0246)	(0.174)	(0.172)
Upstream FDI	0.0131	0.0125	0.0720*	0.0997**
	(0.00801)	(0.00781)	(0.0404)	(0.0402)
Observations	987,022	785,271	987,022	785,271

Dependent variable is a zero-one dummy variable for whether or not the enterprise changed sector. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.9: Basic Regressions of Revenue on Tariffs

The dependent variable is log of revenue

	All enterprises		Non-Exporters Only		All enterprises		Non-Exporters Only	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
output_tariff	-0.0258***	0.0523	-0.0309***	0.0526	-0.0171**	0.0471	-0.0243***	0.0619
	(0.0076)	(0.0461)	(0.0078)	(0.0439)	(0.0081)	(0.0501)	(0.0088)	(0.0477)
downstream_tariff	0.0334**	0.522***	0.00361	0.375***	0.0711***	1.094***	0.0326	0.730***
	(0.0168)	(0.1270)	(0.0176)	(0.1380)	(0.0218)	(0.1960)	(0.0243)	(0.2180)
upsrteam_tariff	0.0175	-0.175	0.017	-0.272	-0.0999***	-0.743***	-0.115***	-0.636**
	(0.0240)	(0.1760)	(0.0241)	(0.1750)	(0.0381)	(0.2690)	(0.0418)	(0.2650)
index_subsidy	0.0990***	0.0994***	0.0856***	0.0855***	0.0951***	0.0956***	0.0819***	0.0821***
	(0.0034)	(0.0034)	(0.0039)	(0.0039)	(0.0034)	(0.0034)	(0.0039)	(0.0039)
index_tax	0.0680***	0.0681***	0.0705***	0.0708***	0.0676***	0.0681***	0.0698***	0.0705***
	(0.0023)	(0.0023)	(0.0026)	(0.0026)	(0.0023)	(0.0023)	(0.0025)	(0.0025)
index_interest	-0.101***	-0.101***	-0.111***	-0.111***	-0.0977***	-0.0980***	-0.107***	-0.107***
	(0.0027)	(0.0027)	(0.0030)	(0.0030)	(0.0027)	(0.0027)	(0.0029)	(0.0030)
exportshare_sector	0.00344	-0.361***	-0.143**	-0.374***	0.441***	-0.188	-0.145	-0.481***
	(0.067)	(0.085)	(0.061)	(0.096)	(0.114)	(0.148)	(0.142)	(0.170)
State_share	0.0466***	0.0470***	0.0440***	0.0440***	0.0481***	0.0474***	0.0458***	0.0455***
	(0.0089)	(0.0089)	(0.0099)	(0.0099)	(0.0088)	(0.0089)	(0.0099)	(0.0099)
Horizontal FDI	-0.0486	-0.0112	-0.0000323	0.057	-0.125	-0.273**	-0.0543	-0.151
	(0.067)	(0.096)	(0.075)	(0.099)	(0.112)	(0.135)	(0.124)	(0.144)
Downstream FDI	0.920***	-0.125	1.007***	0.416	0.51	-2.661***	0.155	-1.814**
	(0.160)	(0.296)	(0.176)	(0.301)	(0.493)	(0.791)	(0.536)	(0.868)
Upstream FDI	0.240***	0.442***	0.229***	0.426***	0.716***	0.546***	0.550***	0.524***
	(0.036)	(0.068)	(0.041)	(0.079)	(0.106)	(0.144)	(0.118)	(0.140)
sector fixed effect	no	no	no	no	yes	yes	yes	yes
Observations	1,037,738	1,037,738	826,072	826,072	1,037,738	1,037,738	826,072	826,072

Standard errors are clustered. Tariffs and revenue are in logs. All specifications include fixed effects for the firm and time. 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 $p < 0.1$.

Table A.10: Cross-sectional relation between revenue and TFP
Dependent variable is log TFP, measured à la Olley-Pakes (OP) or OLS with fixed effects (FE)

	OP (1)	FE (2)	OP (3)	FE (4)
log revenue	0.191***	0.204***	0.188***	0.197***
	(0.0074)	(0.0062)	(0.0077)	(0.0061)
Time Fixed Effects	Yes	Yes	Yes	Yes
Sector Fixed Effects	No	No	Yes	Yes
Observations	1,012,444	1,012,444	1,012,444	1,012,444
R-squared	0.279	0.319	0.453	0.455
Number of firm ID's	327,924	327,924	327,924	327,924

Robust standard errors in parenthesis. *** indicates p-values less than 1%.

A.3 Robustness of Empirical Results

Main Specification We conduct robustness checks on the main regression specification:

$$y_{it} = \beta_1 \ln \text{Output Tariff}_{j(i,t)t} + \beta_2 \ln \text{Downstream Tariff}_{j(i,t)t} + \gamma_1 X_{j(i,t)t} + \gamma_2 X_{i,t} + \alpha_i + \alpha_t + \varepsilon$$

Tables A.11, A.12 and A.13 show the coefficient on output and downstream tariffs β_1, β_2 for each robustness check. The dependent variable is revenue TFP measured à la Olley Pakes in Table A.11, the two measures of introduction of new goods in Table A.12, and the ranking of sector skill intensity in Table A.13. All specifications include time and firm fixed effects and control variables described in Appendix A.1. When the dependent variable is TFP, we also include sector fixed effects and a dummy for when the firm switches sectors.

Exercise 1 includes all multinationals and state-owned enterprises (SOE's) excluded from the main specification. Exercises 2 and 3 check if the results contrasting between output and downstream tariffs are affected by the collinearity between these tariff measures. We drop one tariff measure from the regression at a time. We do two exercises to address the concern that selection drives our results. Exercise 4 keeps only a balanced panel of establishments that survived all ten years of our data.

In exercise 5, we follow Wooldridge (2002) and construct a Heckman-type correction in the context of a panel dataset with firm fixed effects and attrition. In each period, we estimate a selection equation using a probit approach and calculating lambda, the inverse Mills ratio, for each parent i. Once a series of lambdas has been estimated for each year and parent, the estimating equations are augmented by these lambdas. We use the establishment's profitability in the previous period as the determinant of survival that does not appear in the estimating equation.

Exercises 6 and 7 drop key sectors from the data. We drop textiles and apparel since these sectors were affected by the phasing out of the Multi-fibre Agreement (MFA). Exercise 8 drops the computer and computer peripherals sector, which experienced large growth due to offshoring. For

Table A.11: Robustness checks on TFP measured à la Olley-Pakes (except line 9)

	all establishments excluding SOEs and multinationals			non-exporters	
	coefficient (std. err)		number of	coeff. (std. err)	number of
	OLS	IV	observations	IV	observations
Baseline specification (main text)					
output tariffs	**-0.0304*** **	**-0.0505*** **	1,037,738	**-0.0617*** **	826,072
	(0.0027)	(0.0169)		(0.0158)	
downstream tariffs	**-0.0179** **	**-0.178*** **		**-0.421*** **	
	(0.0070)	(0.0627)		(0.0650)	
1. including SOE's and multinationals					
output tariffs	-0.0271***	-0.0123	1,495,411	-0.0294**	1,047,907
	(0.00228)	(0.0168)		(0.0142)	
downstream tariffs	-0.0266***	-0.0798		-0.376***	
	(0.00637)	(0.0565)		(0.0630)	
2. drop downstream tariffs					
output tariffs	-0.0301***	-0.0722***	1,037,738	-0.0876***	826,072
	(0.00266)	(0.0202)		(0.0173)	
3. drop ouput tariffs					
downsream tariffs	-0.0204***	-0.104	1,037,738	-0.325***	826,072
	(0.00693)	(0.0659)		(0.0709)	
4. balanced panel					
output tariffs	-0.0536***	-0.0561***	65,809	-0.0659***	47,128
	(0.0070)	(0.0073)		(0.0224)	
downstream tariffs	-0.0616***	-0.0678***		-0.648***	
	(0.0164)	(0.0179)		(0.1320)	
5. Include Mills ratio					
output tariffs	-0.0326***	-0.0272*	850,582	-0.0386***	671,237
	(0.0027)	(0.0162)		(0.0032)	
downstream tariffs	-0.131***	-0.189**		-0.167***	
	(0.0171)	(0.0851)		(0.0206)	
6. Excluding textiles and apparel					
output tariffs	-0.0322***	-0.0727***	849,870	-0.103***	706,931
	(0.00273)	(0.0192)		(0.0179)	
downstream tariffs	-0.00880	-0.509***		-0.752***	
	(0.00754)	(0.0834)		(0.0960)	
7. Excluding computers and peripherals					
output tariffs	-0.0307***	-0.0504***	1,037,243	-0.0616***	825,647
	(0.00268)	(0.0169)		(0.0158)	
downstream tariffs	-0.0183***	-0.179***		-0.421***	
	(0.00698)	(0.0626)		(0.0648)	

Robustness checks on TFP measured à la Olley-Pakes (continued from previous page)

	all establishments excluding SOEs and multinationals			non-exporters	
	coefficient (std. err)		number of	coeff. (std. err)	number of
	OLS	IV	observations	IV	observations
Baseline specification (main text)					
output tariffs	**-0.0304*** **	**-0.0505*** **	1,037,738	**-0.0617*** **	826,072
	(0.0027)	(0.0169)		(0.0158)	
downstream tariffs	**-0.0179** **	**-0.178*** **		**-0.421*** **	
	(0.0070)	(0.0627)		(0.0650)	
8. Including tariffs in estimating TFP					
output tariffs	-0.0323***	-0.0491***	1,004,678	-0.0586***	797,937
	(0.00280)	(0.0174)		(0.0163)	
downstream tariffs	-0.0149**	-0.150**		-0.416***	
	(0.00735)	(0.0657)		(0.0680)	
9. TFP estimated à la Ackerberg, Caves, Frazer (2015)					
output tariffs	-0.0619***	-0.120**	1,036,517	-0.169***	825,221
	(0.0057)	(0.0549)		(0.0513)	
downstream tariffs	-0.0421	-0.568***		-1.252***	
	(0.0284)	(0.1280)		(0.1310)	

Table A.12: Robustness checks on the introduction of new goods

Dependent variable is the share of new goods in sales

	all establishments excluding SOEs and multinationals			non-exporters	
	coefficient (std. err) OLS	IV	number of observations	coeff. (std. err) IV	number of observations
Baseline specification (main text)					
output tariffs	**-0.000356**	**-0.0157****	1,037,738	**-0.00976****	826,072
	(0.0012)	(0.0068)		(0.0045)	
downstream tariffs	**-0.00372**	**-0.0272**		**-0.0313****	
	(0.0024)	(0.0184)		(0.0147)	
1. including SOE's and multinationals					
output tariffs	0.00141	-0.0122	1,495,411	-0.00703*	1,047,907
	(0.000968)	(0.00845)		(0.00395)	
downstream tariffs	-0.00252	-0.0208		-0.0198	
	(0.00199)	(0.0170)		(0.0123)	
2. drop downstream tariffs					
output tariffs	-0.000277	-0.0186**	1,037,738	-0.0110**	826,072
	(0.00120)	(0.00794)		(0.00471)	
3. drop ouput tariffs					
downstream tariffs	-0.00369	-0.00861	1,037,738	-0.0200	826,072
	(0.00235)	(0.0160)		(0.0132)	
4. balanced panel					
output tariffs	-0.000430	-0.0192	65,809	-0.0110	47,128
	(0.00343)	(0.0138)		(0.00869)	
downstream tariffs	-0.00590	-0.0585		-0.0639**	
	(0.00671)	(0.0383)		(0.0321)	
5. Include Mills ratio					
output tariffs	0.000606	-0.0129**	850,582	-0.0100**	671,237
	(0.00118)	(0.00625)		(0.00428)	
downstream tariffs	-0.00436*	-0.0313*		-0.0363**	
	(0.00265)	(0.0184)		(0.0157)	
6. Excluding textiles and apparel					
output tariffs	-0.000361	-0.0169**	849,870	-0.00999**	706,931
	(0.00124)	(0.00750)		(0.00479)	
downstream tariffs	0.00150	-0.0256		-0.0292	
	(0.00271)	(0.0216)		(0.0204)	
7. Excluding computers and peripherals					
output tariffs	-0.000474	-0.0157**	1,037,243	-0.00978**	825,647
	(0.00121)	(0.00678)		(0.00445)	
downstream tariffs	-0.00359	-0.0273		-0.0315**	
	(0.00237)	(0.0185)		(0.0148)	

Robustness checks on the introduction of new goods (continued from previous page)

Dependent variable is a 0-1 dummy of whether the firm introduced a new product in the year

	all establishments excluding SOEs and multinationals			non-exporters	
	coefficient (std. err)		number of	coeff. (std. err)	number of
	OLS	IV	observations	IV	observations
Baseline specification (main text)					
output tariffs	**-0.000687**	**-0.0405****	1,037,738	**-0.0279*****	826,072
	(0.0029)	(0.0168)		(0.0102)	
downstream tariffs	**0.00777**	**-0.0533**		**-0.0423**	
	(0.0078)	(0.0399)		(0.0266)	
1. including SOE's and multinationals					
output tariffs	0.00134	-0.0446***	1,495,411	-0.0195**	1,047,907
	(0.00207)	(0.0172)		(0.00838)	
downstream tariffs	0.00548	-0.0584*		-0.0130	
	(0.00598)	(0.0347)		(0.0236)	
2. drop downstream tariffs					
output tariffs	-0.000852	-0.0461**	1,037,738	-0.0295***	826,072
	(0.00290)	(0.0188)		(0.0106)	
3. drop ouput tariffs					
downstream tariffs	0.00782	-0.00547	1,037,738	-0.0100	826,072
	(0.00778)	(0.0362)		(0.0232)	
4. balanced panel					
output tariffs	0.00317	-0.0650**	65,809	-0.0409**	47,128
	(0.00713)	(0.0272)		(0.0186)	
downstream tariffs	0.00926	-0.152*		-0.132**	
	(0.0152)	(0.0827)		(0.0651)	
5. Include Mills ratio					
output tariffs	0.00140	-0.0292*	850,582	-0.0282***	671,237
	(0.00328)	(0.0159)		(0.00943)	
downstream tariffs	-0.00116	-0.0819**		-0.0577**	
	(0.00565)	(0.0404)		(0.0279)	
6. Excluding textiles and apparel					
output tariffs	-0.000124	-0.0412**	849,870	-0.0269**	706,931
	(0.00298)	(0.0184)		(0.0109)	
downstream tariffs	0.0257**	-0.0236		-0.0234	
	(0.0103)	(0.0490)		(0.0354)	
7. Excluding computers and peripherals					
output tariffs	-0.000784	-0.0405**	1,037,243	-0.0279***	825,647
	(0.00292)	(0.0168)		(0.0102)	
downstream tariffs	0.00806	-0.0534		-0.0425	
	(0.00783)	(0.0399)		(0.0266)	

Table A.13: Robustness checks on switches to skill-intensive sectors

Dependent variable is the ranking of skill intensity of the sector

	all establishments excluding SOEs and multinationals			non-exporters	
	coefficient (std. err)		number of	coeff. (std. err)	number of
	OLS	IV	observations	IV	observations
Baseline specification (main text)					
output tariffs	**-17.82*** **	**-26.20*** **	1,037,738	**-19.27*** **	826,072
	(1.00)	(3.81)		(3.14)	
downstream tariffs	**6.914*** **	**-33.44*** **		**-31.39*** **	
	(1.34)	(7.40)		(7.49)	
1. including SOE's and multinationals					
output tariffs	-15.83***	-40.10***	1,495,411	-18.70***	1,047,907
	(0.970)	(4.997)		(2.743)	
downstream tariffs	8.834***	-49.73***		-28.79***	
	(1.419)	(7.862)		(6.143)	
2. drop downstream tariffs					
output tariffs	-17.96***	-29.69***	1,037,738	-20.47***	826,072
	(0.996)	(4.287)		(3.278)	
3. drop output tariffs					
downstream tariffs	8.260***	-2.523	1,037,738	-9.073	826,072
	(1.452)	(5.669)		(5.908)	
4. balanced panel					
output tariffs	-14.49***	-23.15***	65,809	-16.50***	47,128
	(1.957)	(4.897)		(4.469)	
downstream tariffs	8.957**	-26.93**		-27.21**	
	(3.850)	(11.89)		(13.43)	
5. Include Mills ratio					
output tariffs	-17.73***	-26.09***	850,582	-19.10***	671,237
	(1.053)	(3.760)		(3.097)	
downstream tariffs	12.66***	-34.74***		-30.03***	
	(2.536)	(7.978)		(7.946)	
6. Excluding textiles and apparel					
output tariffs	-17.87***	-29.36***	849,870	-21.73***	706,931
	(1.027)	(4.141)		(3.349)	
downstream tariffs	-3.432**	-22.97**		-27.43***	
	(1.418)	(9.341)		(9.872)	
7. Excluding computers and peripherals					
output tariffs	-17.86***	-26.19***	1,037,243	-19.25***	825,647
	(1.004)	(3.822)		(3.150)	
downstream tariffs	6.777***	-33.48***		-31.43***	
	(1.348)	(7.409)		(7.510)	

the TFP regressions, exercise 9 includes tariffs in the first stage of the TFP estimate, and exercise 10 measures TFP following Caves, Fraser, and Ackerberg (2015).

When the dependent variable is revenue TFP, the coefficient on output tariffs is negative and statistically significant in all specifications. The results confirm that the coefficient on downstream tariffs is nearly ten times larger in all IV specifications with only non-exporters. The only exception is when the sample includes all multinational and SOE's. Multinationals are generally more engaged in offshoring and exporting and may be less influenced by the domestic market. They also may have more difficulty tailoring their products to domestic tastes or coupling their products with non-tradable services.

When the dependent variable is sectoral skill intensity in Table A.13, the coefficient of interest, on output tariffs is negative and significant in all specifications, OLS and IV, including all firms and only non-exporting firms. The results are also very robust when the dependent variable is a 0-1 dummy for whether or not the firm introduces a new product. It is large, negative and statistically significant in all specifications especially when we include only non-exporting firms. When the dependent variable is the share of new goods in sales the result is not robust in the OLS, but it holds in our preferred specification, the IV with only non-exporting firms. The exception is when we include only a balanced panel. Firms that survive through the ten years or our sample are more likely to have introduced successful products that hold a large share of sales. Like in the main text, the coefficients on downstream tariffs are not very robust and they are generally smaller in absolute value or not significantly larger than the coefficient on output tariffs when the dependent variable measures the introduction of new goods or switches to skill-intensive sectors.

To summarize, the results in the main text hold in all specifications when we include only non-exporting firms. Tariff cuts are associated with increases in TFP, the introduction of new goods, and shifts to more skill-intensive sectors. The coefficient on output tariffs is larger for downstream than for downstream tariffs when the dependent variable is revenue TFP, and not when the dependent variable measures the introduction of new goods or switches to skill-intensive sectors. Since import competition drives our results, we expect them to be stronger for this subsample of non-exporters.

Quartiles of Sales We repeat these robustness checks in the specification in which the independent variable output tariffs is substituted with an interaction term of output tariffs with a dummy for each quartile of sales in year $t-1$, plus each of the four dummy variables. We do not repeat the balanced-panel regressions because only 6,600 firms survive in all years of our sample and these firms are not well represented in the lower quartiles of sales.

The results are in Tables A.14, A.15, and A.16. The quartile regressions in the main text had two messages. First, the output tariffs is smaller (more negative) in smallest quartiles of sales relative to the larger quartiles. Like in the main text, this result only holds in the OLS specifications not in the IV. Also like in the main text, there is no systematic differences across quartiles in the regressions of new goods or sectoral skill intensity across quartile of sales. Second, the coefficient on output tariffs interacted with the first (smallest) quartile of sales is negative, irrespective of whether the dependent variable is revenue TFP, the introduction of new goods or sectoral skill intensity. This second result is robust in all Tables A.14, A.15, and A.16. In the model, small firms in sectors that disproportionately decrease tariffs only increase markup and differentiation if fixed costs to differentiate are small. And large and widespread decreases in tariffs in the model leads to overall increases in differentiation if fixed costs to differentiate are small.

B Theory Appendix

We prove Propositions 1, 2 and 3. We also show that the set of differentiated firms is not convex in productivity even when unit costs do not change with differentiation.

B.1 Exit

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

Claim 1. Suppose by contradiction that i firm with costs (c_{iL}, c_{iD}) enters and a firm j with $(c_{jL}, c_{jD}) \ll (c_{iL}, c_{iD})$ does not enter. If firm i differentiates its product, then trivially, firm j would make positive profits from entering and differentiating. Let firm j be the highest-cost firm that does not enter and that has some firms with costs higher than it enter. Consider the subgame perfect equilibrium where firm j enters and does not differentiate. If any of the subsequent firms remain in the market, then firm j must make positive profits in this subgame, since other firms have costs higher than j. So, the entry of firm j must induce exit from all subsequent firms. This is a contradiction because firm j's profits in this subgame equilibrium must be strictly higher than firm i' profit, $\pi_i \geq 0$. ■

B.2 Numerical Example

The operating profits in the numerical example are in Table B.1.

B.3 Product Differentiation and Productivity

Fix $\hat{\mathbf{c}}_{-iL}$ and the ratio of unit costs c_{iD}/c_{iL}. If the set of firm productivity parameters $\phi_i \equiv (c_{iL})^{-1}$ 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 $c_{Di}/c_{Li} \geq 1$, and (ii) it is unbounded if differentiation decreases unit costs $c_{Di}/c_{Li} < 1$. The net gain from product differentiation $\pi_D(c_{iD}) - \pi_L(c_{iL}, \hat{\mathbf{c}}_{-iL})$ strictly increases if $\hat{\mathbf{c}}_{-iL}$ decreases or if $\hat{\mathbf{c}}_{-iL}$ is augmented with new elements (competitors).

Proof. We omit the firm's subscript i, and without loss of generality, write its costs as $c_{iL} = c_L/\phi$ and $c_{iD} = c_D/\phi$ where ϕ is the firm's productivity. (Obviously, nothing changes if we set $c_L = 1$.)

Step 1: Limits of profits. For a less-differentiated firm, $\lim_{\phi\to\infty} s = 1$, $\lim_{\phi\to\infty} \epsilon = \eta$ and

Table A.14: Robustness of TFP regressions on quartiles of sales interacted with tariffs

Dependent variable: Revenue TFP á la Olley-Pakes

1. Basic regression including SOE's and multinationals			
	All establishments		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0272***	0.0165	-0.00254
	(0.00292)	(0.0174)	(0.0156)
output_tariff*q2	-0.0258***	-0.00187	-0.0169
	(0.00263)	(0.0173)	(0.0151)
output_tariff*q3	-0.0234***	0.0166	-0.00280
	(0.00256)	(0.0171)	(0.0153)
output_tariff*q4 (largest)	-0.0202***	0.0156	-0.00673
	(0.00260)	(0.0165)	(0.0152)
p-value H_0 : tariff*q1 = tariff*q4	0.0045	0.91	0.69
number of observations	1,054,525	1,054,525	713,687
2. Dropping control downstream tariffs			
	All establishments excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0334***	-0.0511***	-0.0669***
	(0.00340)	(0.0197)	(0.0182)
output_tariff*q2	-0.0300***	-0.0447**	-0.0603***
	(0.00313)	(0.0206)	(0.0186)
output_tariff*q3	-0.0259***	-0.0234	-0.0343*
	(0.00313)	(0.0213)	(0.0197)
output_tariff*q4 (largest)	-0.0238***	-0.0276	-0.0399**
	(0.00326)	(0.0194)	(0.0182)
p-value H_0 : tariff*q1 = tariff*q4	0.0011	0.044	0.0409
number of observations	701,765	701,765	548,283
3. Dropping textiles and apparel			
	All establishments excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0354***	-0.0340*	-0.0625***
	(0.00358)	(0.0183)	(0.0185)
output_tariff*q2	-0.0314***	-0.0336*	-0.0645***
	(0.00326)	(0.0196)	(0.0194)
output_tariff*q3	-0.0265***	-0.0347*	-0.0637***
	(0.00327)	(0.0206)	(0.0206)
output_tariff*q4 (largest)	-0.0250***	-0.0428**	-0.0760***
	(0.00338)	(0.0188)	(0.0198)
p-value H_0 : tariff*q1 = tariff*q4	0.0009	0.46	0.347
number of observations	574,845	574,845	470,520

Robustness of TFP regressions on quartiles of sales interacted with tariffs (cont.)

Dependent variable: Revenue TFP á la Olley-Pakes

4. Dropping computers and peripherals	All establishments excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0338***	-0.0331*	-0.0432***
	(0.00342)	(0.0169)	(0.0167)
output_tariff*q2	-0.0304***	-0.0270	-0.0397**
	(0.00314)	(0.0179)	(0.0175)
output_tariff*q3	-0.0263***	-0.00876	-0.0178
	(0.00315)	(0.0190)	(0.0187)
output_tariff*q4 (largest)	-0.0242***	-0.0131	-0.0258
	(0.00328)	(0.0168)	(0.0174)
p-value H_0 : tariff*q1 = tariff*q4	0.0012	0.0898	0.1979
number of observations	701,523	701,523	548,074

5. Include policy variables in the first stage of TFP estimation	All establishments excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0337***	-0.0318*	-0.0389**
	(0.00349)	(0.0173)	(0.0170)
output_tariff*q2	-0.0309***	-0.0241	-0.0334*
	(0.00324)	(0.0183)	(0.0176)
output_tariff*q3	-0.0271***	-0.00737	-0.0147
	(0.00323)	(0.0189)	(0.0188)
output_tariff*q4 (largest)	-0.0262***	-0.0123	-0.0238
	(0.00340)	(0.0172)	(0.0177)
p-value H_0 : tariff*q1 = tariff*q4	0.013	0.1096	0.2776
number of observations	680,432	680,432	530,411

6. TFP measured à la Ackerberg, Caves, Frazer (2015)	All establishments excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.0538***	-0.0633	-0.107**
	(0.00742)	(0.0554)	(0.0520)
output_tariff*q2	-0.0518***	-0.108**	-0.143***
	(0.00673)	(0.0523)	(0.0472)
output_tariff*q3	-0.0493***	-0.0913	-0.139***
	(0.00669)	(0.0582)	(0.0518)
output_tariff*q4 (largest)	-0.0498***	-0.0604	-0.110**
	(0.00727)	(0.0533)	(0.0526)
p-value H_0 : tariff*q1 = tariff*q4	0.6176	0.907	0.909
number of observations	700,756	700,756	547,596

Table A.15: Robustness of regressions of new goods on quartiles of sales interacted with tariffs

Dependent variable: share of new products in sales

1. Include SOE's and multinationals	All establishments		Non-exporters
	OLS	IV	IV
output_tariff*q1	0.00154	-0.0177**	-0.0136***
	(0.00117)	(0.00843)	(0.00500)
output_tariff*q2	0.00143	-0.0144*	-0.00957*
	(0.00115)	(0.00850)	(0.00498)
output_tariff*q3	0.00148	-0.00896	-0.00322
	(0.00118)	(0.00863)	(0.00497)
output_tariff*q4 (largest)	0.00165	-0.0105	-0.00643
	(0.00137)	(0.00906)	(0.00552)
test q1 = q4, pvalue	0.928	0.042	0.0732
number of observations	1,054,525	1,054,525	713,687
2. Drop control downstream tariffs	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	0.000604	-0.0187**	-0.0141**
	(0.00144)	(0.00864)	(0.00614)
output_tariff*q2	0.000575	-0.0209**	-0.0136**
	(0.00141)	(0.00865)	(0.00604)
output_tariff*q3	0.000228	-0.0181**	-0.0111*
	(0.00153)	(0.00893)	(0.00630)
output_tariff*q4 (largest)	-0.000806	-0.0220**	-0.0139**
	(0.00179)	(0.00936)	(0.00640)
test q1 = q4, pvalue	0.3923	0.5213	0.9583
number of observations	701,765	701,765	548,283
3. Dropping textiles and apparel	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	0.000583	-0.0135*	-0.00996
	(0.00150)	(0.00794)	(0.00606)
output_tariff*q2	2.59e-05	-0.0156*	-0.0122**
	(0.00149)	(0.00814)	(0.00609)
output_tariff*q3	-0.000232	-0.0170**	-0.0120*
	(0.00162)	(0.00853)	(0.00646)
output_tariff*q4 (largest)	-0.000461	-0.0209**	-0.0147**
	(0.00185)	(0.00922)	(0.00672)
test q1 = q4, pvalue	0.5483	0.1748	0.3702
number of observations	574,845	574,845	470,520
4. Dropping computers and peripherals	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	0.000517	-0.0151**	-0.0124**
	(0.00144)	(0.00746)	(0.00583)
output_tariff*q2	0.000489	-0.0169**	-0.0116**
	(0.00141)	(0.00747)	(0.00575)
output_tariff*q3	7.99e-05	-0.0150*	-0.0100
	(0.00153)	(0.00786)	(0.00612)
output_tariff*q4 (largest)	-0.00103	-0.0193**	-0.0134**
	(0.00179)	(0.00835)	(0.00629)
test q1 = q4, pvalue	0.3493	0.4232	0.8416
number of observations	701,523	701,523	548,074

Robustness of regressions of new goods on quartiles of sales interacted with tariffs (cont)

Dependent variable: 0-1 dummy of whether the firm introduced a new product in the year

1. Include SOE's and multinationals	All establishments		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.00145	-0.0708***	-0.0371***
	(0.00244)	(0.0179)	(0.0103)
output_tariff*q2	2.15e-05	-0.0589***	-0.0269***
	(0.00238)	(0.0179)	(0.0104)
output_tariff*q3	0.00187	-0.0356*	-0.00422
	(0.00236)	(0.0183)	(0.0109)
output_tariff*q4 (largest)	0.00215	-0.0281	-0.0137
	(0.00269)	(0.0189)	(0.0115)
test q1 = q4, pvalue	0.1808	0.0000	0.0034
number of observations	1,054,525	1,054,525	713,687
2. Drop control downstream tariffs	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.00159	-0.0581***	-0.0354***
	(0.00346)	(0.0203)	(0.0130)
output_tariff*q2	0.000597	-0.0414**	-0.0279**
	(0.00328)	(0.0196)	(0.0126)
output_tariff*q3	0.000798	-0.0357*	-0.0187
	(0.00343)	(0.0208)	(0.0138)
output_tariff*q4 (largest)	-0.00224	-0.0325	-0.0301**
	(0.00375)	(0.0211)	(0.0137)
test q1 = q4, pvalue	0.8587	0.0243	0.6099
number of observations	701,765	701,765	548,283
3. Dropping textiles and apparel	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.000524	-0.0445**	-0.0246*
	(0.00356)	(0.0195)	(0.0129)
output_tariff*q2	0.000224	-0.0261	-0.0229*
	(0.00345)	(0.0189)	(0.0127)
output_tariff*q3	0.00102	-0.0303	-0.0189
	(0.00357)	(0.0205)	(0.0141)
output_tariff*q4 (largest)	0.000472	-0.0356*	-0.0339**
	(0.00384)	(0.0210)	(0.0145)
test q1 = q4, pvalue	0.7915	0.4551	0.3871
number of observations	574,845	574,845	470,520
4. Dropping computers and peripherals	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-0.00135	-0.0513***	-0.0331***
	(0.00347)	(0.0184)	(0.0124)
output_tariff*q2	0.000840	-0.0338*	-0.0249**
	(0.00329)	(0.0177)	(0.0120)
output_tariff*q3	0.00107	-0.0294	-0.0171
	(0.00344)	(0.0191)	(0.0134)
output_tariff*q4 (largest)	-0.00195	-0.0268	-0.0295**
	(0.00378)	(0.0194)	(0.0135)
test q1 = q4, pvalue	0.8704	0.0329	0.7286
number of observations	701,523	701,523	548,074

Table A.16: Robustness of regressions of sectoral skill intensity on quartiles of sales interacted with tariffs

Dependent variable: Ranking of sectors according to skill intensity
(Higher ranking corresponds to higher skill intensity.)

1. Include SOE's and multinationals	All establishments		Non-exporters
	OLS	IV	IV
output_tariff*q1	-15.54***	-34.83***	-14.01***
	(0.991)	(4.924)	(2.951)
output_tariff*q2	-15.40***	-33.49***	-13.05***
	(1.013)	(4.764)	(2.809)
output_tariff*q3	-15.23***	-34.20***	-15.16***
	(1.019)	(4.744)	(2.825)
output_tariff*q4 (largest)	-14.79***	-35.00***	-16.24***
	(1.035)	(4.839)	(3.002)
test q1 = q4, pvalue	0.1163	0.9008	0.1235
number of observations	1,054,525	1,054,525	713,687
2. Drop control downstream tariffs	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-17.80***	-25.11***	-17.00***
	(1.064)	(4.363)	(3.607)
output_tariff*q2	-17.73***	-23.59***	-14.98***
	(1.066)	(4.111)	(3.444)
output_tariff*q3	-17.52***	-24.03***	-16.14***
	(1.074)	(4.211)	(3.537)
output_tariff*q4 (largest)	-17.09***	-26.62***	-18.33***
	(1.099)	(4.262)	(3.562)
test q1 = q4, pvalue	0.2143	0.3736	0.4742
number of observations	701,765	701,765	548,283
3. Dropping textiles and apparel	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-17.98***	-23.81***	-17.42***
	(1.100)	(4.148)	(3.594)
output_tariff*q2	-17.73***	-23.38***	-16.20***
	(1.100)	(3.998)	(3.513)
output_tariff*q3	-17.38***	-23.31***	-17.16***
	(1.110)	(4.109)	(3.638)
output_tariff*q4 (largest)	-16.54***	-26.88***	-20.06***
	(1.138)	(4.227)	(3.775)
test q1 = q4, pvalue	0.0259	0.0906	0.1752
number of observations	574,845	574,845	470,520
4. Dropping computers and peripherals	All excluding SOEs and multinationals		Non-exporters
	OLS	IV	IV
output_tariff*q1	-17.75***	-21.34***	-15.51***
	(1.070)	(3.919)	(3.448)
output_tariff*q2	-17.66***	-19.57***	-13.39***
	(1.073)	(3.670)	(3.290)
output_tariff*q3	-17.42***	-20.57***	-15.07***
	(1.082)	(3.838)	(3.452)
output_tariff*q4 (largest)	-16.98***	-23.34***	-17.67***
	(1.108)	(3.901)	(3.510)
test q1 = q4, pvalue	0.1765	0.2521	0.2626
number of observations	701,523	701,523	548,074

Table B.1: Operating profits (before fixed costs) in the numerical example

Panel A: Initial			
	firm 1	firm 2	firm 3
cost $c_{iL} = c_{iD}$	**1.0**	1.1	1.2
π_D	0.148	0.122	0.103
$\mathcal{L}_S \downarrow$		π_L	
$\{1,2,3\}$	0.092	0.064	0.045
$\{1,2\}$	0.107	0.075	
$\{1,3\}$	0.114		0.058
$\{2,3\}$		0.088	0.064

Panel B: After decrease in c_1			
	firm 1	firm 2	firm 3
cost $c_{iL} = c_{iD}$	**0.9**	1.1	1.2
π_D	0.183	0.122	0.103
$\mathcal{L}_S \downarrow$		π_L	
{1,2,3}	0.126	0.058	0.041
{1,2}	0.143	0.067	
{1,3}	0.150		0.051
{2,3}		0.088	0.064

$\lim_{\phi\to\infty} P_L = \frac{\eta c_L}{(\eta-1)\phi}$. We use these limits below,

$$\lim_{\phi\to\infty}(\pi_D - \pi_L) = \lim_{\phi\to\infty} \overline{P}^{\eta-1}\left[\frac{1}{\eta}\left(\frac{\eta c_D}{(\eta-1)\phi}\right)^{1-\eta} - \frac{P_L^{\sigma-\eta}}{\epsilon_L}\left(\frac{\epsilon_L c_L}{(\epsilon_L-1)\phi}\right)^{1-\sigma}\right]$$
$$= \overline{P}^{\eta-1}\left[\frac{1}{\eta}\left(\frac{\eta c_D}{(\eta-1)\phi}\right)^{1-\eta} - \frac{1}{\eta}\left(\frac{\eta c_L}{(\eta-1)\phi}\right)^{1-\eta}\right]$$
$$= \overline{P}^{\eta-1}\frac{1}{\eta}\left(\frac{\eta}{(\eta-1)\phi}\right)^{1-\eta}\left[c_D^{1-\eta} - c_L^{1-\eta}\right]$$

The term outside the brackets tends to infinity. The term in the square brackets is independent of ϕ and satisfies

$$\left[c_D^{1-\eta} - c_L^{1-\eta}\right] < 0 \qquad \text{if } c_D > c_L$$
$$\left[c_D^{1-\eta} - c_L^{1-\eta}\right] = 0 \qquad \text{if } c_D = c_L$$
$$\left[c_D^{1-\eta} - c_L^{1-\eta}\right] > 0 \qquad \text{if } c_D < c_L$$

This completes the case $c_D < c_L$ for which convexity does not necessarily hold.

Step 2: Convexity when $c_D \geq c_L$.

Step 2.1. Get $\frac{d\pi}{d\phi}$. The profit of a downstream firm is

$$\pi = \max_p \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma}(p - c_n/\phi)$$

Applying the Envelope Theorem, at the optimal price, $\frac{d\pi}{d\phi} = \frac{\partial\pi}{\partial\phi}$

$$\begin{aligned}
\frac{\partial\pi}{\partial\phi} &= \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma} \frac{c_n}{\phi^2} \\
&= \frac{\pi}{\phi}\left(\frac{c_n/\phi}{p - c_n/\phi}\right) \\
&= (\epsilon - 1)\frac{\pi}{\phi} \qquad \text{(B.1)}
\end{aligned}$$

where the last line uses $p = \left(\frac{\epsilon}{\epsilon-1}\right)\frac{c_n}{\phi}$. For differentiated firms, $\epsilon = \eta$.

Step 2.2. Define $G = \pi_D - \pi_L$ as the gain from differentiation gross of fixed costs. A necessary condition for a maximum of the gross gain from differentiating $G(\phi)$ is

$$G'(\phi) = 0 \quad \Rightarrow \quad (\eta - 1)\pi_D = (\epsilon - 1)\pi_L. \qquad \text{(B.2)}$$

Step 2.3. Let s be the market share of the firm in $\mathcal{L}$ when it does not differentiate its product. Clearly, s is strictly increasing in ϕ. To prove that there a unique s satisfying equation (B.2), we rewrite the condition above as a function of s. Denote the markup of the firm with μ_D if it is differentiated, and μ_L otherwise. Substituting the expression for profit in (B.2), we have:

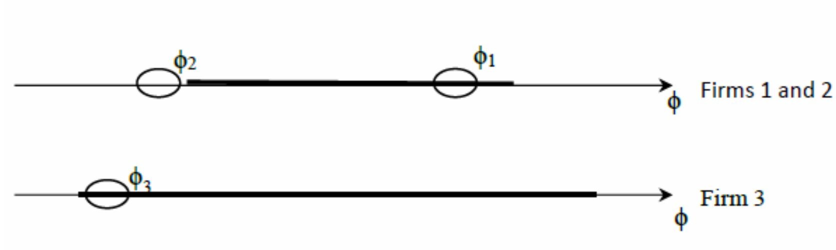
$$\begin{aligned}
\frac{\eta-1}{\eta} p_D^{1-\eta} &= \frac{\epsilon-1}{\epsilon} P_L^{1-\eta}\left(\frac{p_L}{P_L}\right)^{1-\sigma} \qquad \text{(B.3)} \\
\frac{(\mu_D c_D/\phi)^{1-\eta}}{\mu_D} &= \frac{P_L^{1-\eta}}{\mu_L} s \\
\equiv \quad \left(\frac{\mu_D c_D}{\mu_L c_L}\frac{\mu_L c_L/\phi}{P_L}\right)^{1-\eta} &= \frac{\mu_D}{\mu_L} s \\
\equiv \quad s^{\frac{\eta-1}{\sigma-1}} &= s\left(\frac{\mu_D}{\mu_L}\right)^{\eta}\left(\frac{c_D}{c_L}\right)^{(\eta-1)} \\
\equiv \quad s &= \left(\frac{\mu_L}{\mu_D}\right)^{\eta\frac{\sigma-1}{\sigma-\eta}}\left(\frac{c_L}{c_D}\right)^{(\eta-1)\frac{\sigma-1}{\sigma-\eta}} \qquad \text{(B.4)}
\end{aligned}$$

When $s = 1$, then the right-hand-side is $(c_L/c_D)^{(\eta-1)\frac{\sigma-1}{\sigma-\eta}}$, less than or equal to one since $c_L \leq c_D$. When $s = 0$, then $\mu_L = \sigma/(\sigma - 1)$ and the right-hand-side is strictly larger than one. Next, we prove that μ_L is a convex function of s. Then these two limits will be enough to prove that the left- and right-hand-sides of (B.4) cross at most once.

Step 2.4. The pricing rule is

$$\mu_L = \frac{\sigma + (\eta - \sigma)s}{\sigma + (\eta - \sigma)s - 1}$$

Figure B.1: Set of productivities ϕ where differentiation is profitable, given $P_{-1L} = P_{-2L} > P_{-3L}$



We must show that $\frac{\partial^2(\mu_L)^a}{\partial s^2} > 0$ where $a > 1$ is a constant.

$$\frac{\partial(\mu_L)^a}{\partial s} = a\mu_L^{a-1} \frac{\sigma - \eta}{(\sigma + (\eta - \sigma)s - 1)^2}$$

It is a positive constant a times the product of two positive and increasing functions of s, μ_L^{a-1} and $(\sigma + (\eta - \sigma)s - 1)^{-2}$. Hence, $\frac{\partial^2(\mu_L)^a}{\partial s^2} > 0$ as we wanted to prove. ■

Two notes on convexity are in order. First, convexity generally does not hold when $c_L > c_D$. By the arguments in steps 2.3 and 2.4, the gain from differentiation, $\pi_D - \pi_L$ has either zero or two critical points when $c_L > c_D$ satisfying equation (B.4). When there are no critical points, then the set of productivity ϕ for which the firm differentiates its product is convex $(\underline{\phi}, \infty)$. When there are two critical points, the first is local maximum and the second is a local minimum. Convexity holds only if the gain from differentiating is strictly larger than the fixed cost $\pi_D - \pi_L - (f_D - f_L) > 0$ at the second critical point.

Second, even when the ratio of unit costs c_{iL}/c_{iD} is the same for all firms, the set of differentiated firms is not necessarily convex in costs c_{iL} in a given equilibrium because firms face different levels of competition in the less-differentiated nest c_{-iL}. We sketch an example where the equilibrium set of differentiated firms is not necessarily convex in productivity.

When c_{iL}/c_{iD} is the same for all firms, we can write firms' units costs as functions of firm-specific productivity ϕ_i: Let $c_{iL} = c_L/\phi_i$ and $c_iD = c_D/\phi_i$ for all i where c_L and c_D are common parameters. Consider an economy with Foreign competition and three domestic firms with productivity parameters $\phi_1 > \phi_2 > \phi_3$. Let $c_D = c_L$ so that the set of differentiated firms is a bounded interval $(\underline{\phi}, \overline{\phi})$ for any given P_{-iL}. We claim that for some parameter values, it is possible to construct a subgame perfect equilibrium with actions in the equilibrium path {*differentiate, not differentiate, differentiate*}. Suppose that in the subgame where firm 1 does not differentiate, then the two other firms differentiate. Then, the level of competition faced by the three firms in the less-differentiated nest is $P_{LF} = P_{-1L} = P_{-2L} > P_{-3L}$. Then, the set of productivity ϕ that makes differentiation profitable is illustrated in Figure B.1 in bold. The set is larger for firm 3 because $P_{-1L} = P_{-2L} > P_{-3L}$, and so it is possible to judiciously pick productivity levels in the regions indicated with an oval such that the proposed equilibrium holds.

B.4 Markup Responses of Firms of Different Sizes

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 $c_{aL} < c_{bL}$. If both firms a and b differentiate their products or if both firms remain less-differentiated, the markup of firm b increases relative to firm a, i.e., μ_b/μ_a increases, where μ_i is the markup of firm i.

Proof. The case where both firms differentiate is in the main text. If both firm remain less-differentiated, they decrease their markups. We must prove that the markup response is greater for firm a than for firm b:

$$\left|\frac{d\mu_a}{\mu_a}\right| > \left|\frac{d\mu_b}{\mu_b}\right|$$

where μ_i is the markup of firm i and $d\mu_b$ is the change given the shock.

In setting prices in the less-differentiated nest, firm i best responds to the other firm's prices. Define

$$P_{-iL}^{1-\sigma} = \sum_{i' \in \mathcal{L}, i' \neq i} p_{i'}^{1-\sigma}.$$

The shock decreases the price of firms in $\mathcal{L}$, excluding firm a and b. Since both a and b respond to it, the shock to P_{-aL} and P_{-bL} is different. We first consider each firm's response to an increase in $P_{-iL}^{1-\sigma}$. For ease of notation, we drop the firm's subscript and define $A = P_{-iL}^{1-\sigma}$. Denote the markup with μ and without loss of generality, we set $c_L = 1$.

Step 1: Derive an expression for $\frac{P_L^{1-\sigma}}{\mu}\frac{d\mu}{dA}$ Using the pricing rule, the markup μ of a less-differentiated firm with unit cost c is implicitly defined as a function of A as

$$\Psi(\mu, A) \quad \equiv \quad \frac{\sigma + (\eta - \sigma)\left(\frac{(\mu c)^{1-\sigma}}{(\mu c)^{1-\sigma} + A}\right)}{\sigma + (\eta - \sigma)\left(\frac{(\mu c)^{1-\sigma}}{(\mu c)^{1-\sigma} + A}\right) - 1} \quad - \quad \mu = 0$$

By the Implicit Function Theorem, $\frac{d\mu}{dA} = -\frac{\Psi_A}{\Psi_\mu}$ where Ψ_x refers to derivative of Ψ with respect to x, following standard notation. Taking derivatives,

$$\Psi_A = \frac{(\eta - \sigma)\left(\frac{(\mu c)^{1-\sigma}}{[(\mu c)^{1-\sigma} + A]^2}\right)}{\left[\sigma + (\eta - \sigma)\left(\frac{(\mu c)^{1-\sigma}}{(\mu c)^{1-\sigma} + A}\right) - 1\right]^2}$$

$$\Psi_\mu = -1 - \frac{\frac{(\sigma - \eta)(\sigma - 1)}{\mu}\left(\frac{A(\mu c)^{1-\sigma}}{[(\mu c)^{1-\sigma} + A]^2}\right)}{\left[\sigma + (\eta - \sigma)\left(\frac{(\mu c)^{1-\sigma}}{(\mu c)^{1-\sigma} + A}\right) - 1\right]^2}$$

Since $\eta < \sigma$, $(\Psi_A, \Psi_\mu) \ll 0$ so that $\frac{d\mu}{dA} = -\frac{\Psi_A}{\Psi_\mu} < 0$, confirming that firms decrease markups in response to tighter competition.

$$\frac{d\mu}{dA} = \frac{(\eta-\sigma)\left(\frac{(\mu c)^{1-\sigma}}{[(\mu c)^{1-\sigma}+A]^2}\right)}{\left[\sigma+(\eta-\sigma)\left(\frac{(\mu c)^{1-\sigma}}{(\mu c)^{1-\sigma}+A}\right)-1\right]^2+\frac{(\sigma-\eta)(\sigma-1)}{\mu}\left(\frac{A(\mu c)^{1-\sigma}}{[(\mu c)^{1-\sigma}+A]^2}\right)}$$

Using the firm's market share $s = (\mu c)^{1-\sigma}/\left[(\mu c)^{1-\sigma}+A\right]$

$$-\frac{P_L^{1-\sigma}}{\mu}\frac{d\mu}{dA} = \frac{(\sigma-\eta)s}{\mu\left[(\sigma-1)-(\sigma-\eta)s\right]^2+(\sigma-\eta)(\sigma-1)s(1-s)} \tag{B.5}$$

Step 2. We now return to the original shock that decreases the price of the competitors of firms a and b in the less-differentiated nest. Note first that since firm a and b are in the same nest, price index P_L is the same for both firms. Define P_{-abL} as the component of the shock that is common to a and b,

$$P_{-abL}^{1-\sigma} = \sum_{i\in\mathcal{L}, i\neq a,b} p_i^{1-\sigma}.$$

The price index of all firm a's competitors is

$$P_{-aL}^{1-\sigma} = P_{-abL}^{1-\sigma} + (\mu_b c_b)^{1-\sigma} \tag{B.6}$$

Totally differentiating μ_a with respect to $P_{-abL}^{1-\sigma}$, we get:

$$\frac{d\mu_a}{dP_{-abL}^{1-\sigma}} = \frac{\partial\mu_a}{\partial P_{-abL}^{1-\sigma}} + (1-\sigma)\frac{p_b^{1-\sigma}}{\mu_b}\frac{\partial\mu_b}{\partial P_{-abL}^{1-\sigma}}\frac{\partial\mu_a}{\partial p_b^{1-\sigma}} \tag{B.7}$$

The equivalent expression for b is

$$\frac{d\mu_b}{dP_{-abL}^{1-\sigma}} = \frac{\partial\mu_b}{\partial P_{-abL}^{1-\sigma}} + (1-\sigma)\frac{p_a^{1-\sigma}}{\mu_a}\frac{\partial\mu_a}{\partial P_{-abL}^{1-\sigma}}\frac{\partial\mu_b}{\partial p_a^{1-\sigma}} \tag{B.8}$$

Note that the partial derivatives $\frac{\partial\mu}{\partial P_{-abL}^{1-\sigma}}$ and $\frac{\partial\mu}{\partial p_i^{1-\sigma}}$ with respect to the price of any competitor i is given by (B.5) because of the linearity of (B.6). Then, combining (B.7) and (B.8), we then have

$$\frac{P_L^{1-\sigma}}{\mu_a}\frac{d\mu_a}{dP_{-abL}^{1-\sigma}} - \frac{P_L^{1-\sigma}}{\mu_b}\frac{d\mu_b}{dP_{-abL}^{1-\sigma}} = \frac{P_L^{1-\sigma}}{\mu_a}\frac{\partial\mu_a}{\partial P_{-abL}^{1-\sigma}} - \frac{P_L^{1-\sigma}}{\mu_b}\frac{\partial\mu_b}{\partial P_{-abL}^{1-\sigma}} + (1-\sigma)(s_b-s_a)\frac{(P_L^{1-\sigma})^2}{\mu_b\mu_a}\frac{\partial\mu_b}{\partial P_{-abL}^{1-\sigma}}\frac{\partial\mu_a}{\partial P_{-abL}^{1-\sigma}}$$

Substituting (B.5),

$$
\begin{aligned}
&\frac{P_L^{1-\sigma}}{\mu_a}\frac{d\mu_a}{dP_{-abL}^{1-\sigma}} - \frac{P_L^{1-\sigma}}{\mu_b}\frac{d\mu_b}{dP_{-abL}^{1-\sigma}} \\
=&\frac{(\eta-\sigma)s_a}{\mu_a\left[(\sigma-1)-(\sigma-\eta)s_a\right]^2+(\sigma-\eta)(\sigma-1)s_a(1-s_a)} - \\
&\frac{(\eta-\sigma)s_b}{\mu_b\left[(\sigma-1)-(\sigma-\eta)s_b\right]^2+(\sigma-\eta)(\sigma-1)s_b(1-s_b)} + \\
&\frac{(1-\sigma)(\sigma-\eta)^2 s_a s_b (s_a-s_b)}{\left\{\mu_a\left[(\sigma-1)-(\sigma-\eta)s_a\right]^2+(\sigma-\eta)(\sigma-1)s_a(1-s_a)\right\}\left\{\mu_b\left[(\sigma-1)(\sigma-\eta)s_b\right]^2+(\sigma-\eta)(\sigma-1)s_b(1-s_b)\right\}} \\
=&\ \frac{(\sigma-\eta)\left\{\mu_a\left[(\sigma-1)-(\sigma-\eta)s_a\right]^2 s_b - \mu_b\left[(\sigma-1)-(\sigma-\eta)s_b\right]^2 s_a\right\}}{\left\{\left[(\sigma-1)-(\sigma-\eta)s_a\right]^2+(\sigma-\eta)(\sigma-1)s_a(1-s_a)\right\}\left\{\left[(\sigma-1)(\sigma-\eta)s_b\right]^2+(\sigma-\eta)(\sigma-1)s_b(1-s_b)\right\}}
\end{aligned}
$$

Since the denominator is positive, we must prove that the numerator is negative so that in absolute value, $\left|\frac{1}{\mu_a}\frac{d\mu_a}{dP_{-abL}^{1-\sigma}}\right| > \left|\frac{1}{\mu_b}\frac{d\mu_b}{dP_{-abL}^{1-\sigma}}\right|$. That is, the following function must be increasing in s:

$$
\frac{(\sigma-\eta)s}{\mu[(\sigma-1)-(\sigma-\eta)s]^2} = \frac{\sigma-\epsilon}{\epsilon(\epsilon-1)}
$$

We have rewritten the expression as a function of the elasticity of demand that the firm faces ϵ which is strictly decreasing in s. Clearly, the function is decreasing in $\epsilon > 1$ since the numerator is decreasing and the denominator is increasing. ■

C Miss-allocation of Labor

Consider any set of discrete choices with the corresponding profit-maximizing prices and market-clearing quantities. Suppose a planner can reallocate labor but not change discrete choices. For any two less-differentiated firms, 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.

Proof. The planner cannot change sets $\mathcal{L}$ and $\mathcal{D}$, but he can reallocate labor to maximize welfare.

His problem is to choose quantities q_i for Home varieties to maximize

$$\max Q = \left[(Q_L)^{\frac{\eta-1}{\eta}} + \sum_{i \in \mathcal{D}} q_i^{\frac{\eta-1}{\eta}} + (Q_D^*)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$\text{subject to} \quad Q_L = \left(\sum_{i \in \mathcal{L}_H} q_i^{\frac{\sigma-1}{\sigma}} + (Q_L^*)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$L = \sum_{i \in \mathcal{L}_H} (c_{iL} q_i) + \sum_{i \in \mathcal{D}_H} (c_{iD} q_i) . \tag{C.1}$$

where Q_D^* and Q_L^* are the aggregate quantities consumed of Foreign goods, which the planner takes as given. The first order conditions with respect to quantity q_L for a less-differentiated firm and quantity q_D for a differentiated firm, where

$$q_L = \lambda^{-\sigma} (c_{iL})^{-\sigma} Q^{\sigma/\eta} (Q_L)^{(\eta-\sigma)/\eta}$$
$$q_D = \lambda^{-\eta} (c_{iD})^{-\eta} Q$$

λ is the Lagrange multiplier for constraint (C.1). Define the aggregate quantities of Home less-differentiated and differentiated goods are respectively,

$$Q_{LH} = \left(\sum_{i \in \mathcal{L}_H} q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$Q_{DH} = \left(\sum_{i \in \mathcal{D}_H} q_i^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

Substituting the first order conditions,

$$\frac{Q_{LH}}{Q_L} = \lambda^{-\sigma} \left(\frac{Q_L}{Q} \right)^{-\sigma/\eta} C_{LH}^{-\sigma}$$

$$\frac{Q_{DH}}{Q} = \lambda^{-\eta} C_{DH}^{-\eta} \tag{C.2}$$

$$\text{where} \quad C_{LH} = \left(\sum_{i \in \mathcal{L} \cap \mathcal{H}} (c_{iL})^{1-\sigma} \right)^{1/(1-\sigma)}$$

$$C_{DH} = \mu_D \left(\sum_{i \in \mathcal{D}} (c_{iD})^{1-\eta} \right)^{1/(1-\eta)}$$

Note that C_{LH} and C_{LH} are not nominal costs, but labor requirements for production of aggregate quantities since there are no prices in the planner's problem. Rearranging the first equation,

$$\frac{Q_L}{Q}\left(\frac{Q_{LH}}{Q_L}\right)^{\eta/\sigma} = \lambda^{-\eta} C_{LH}^{-\eta}$$

Dividing it by (C.2),

$$\frac{Q_L^W}{Q_D^W}\left(\frac{Q_{LH}^W}{Q_L^W}\right)^{\eta/\sigma} = \left(\frac{C_{LH}}{C_{DH}}\right)^{-\eta} \tag{C.3}$$

where the superscript W indicates the planner's solution. Following the same steps, the equivalent expression for the market (superscript M) is

$$\frac{Q_L^M}{Q_D^M}\left(\frac{Q_{LH}^M}{Q_L^M}\right)^{\eta/\sigma} = \left(\frac{P_{LH}}{P_{DH}}\right)^{-\eta}$$

$$\text{where} \quad P_{LH} = w\left(\sum_{i\in\mathcal{L}\cap\mathcal{H}} (c_{iL})^{1-\sigma}\right)^{1/(1-\sigma)}$$

$$P_{DH} = w\mu_D\left(\sum_{i\in\mathcal{L}\cap\mathcal{H}} (c_{iD})^{1-\sigma}\right)^{1/(1-\sigma)}$$

Dividing these market quantities by the planner's (C.3), we have

$$\frac{Q_L^M/Q_D^M(Q_{LH}^M/Q_L^M)^{\eta/\sigma}}{Q_L^W/Q_D^W(Q_{LH}^W/Q_L^W)^{\eta/\sigma}} = \left(\frac{P_{LH}/P_{DH}}{C_{LH}/C_{DH}}\right)^{-\eta} > 1$$

where the inequality holds because markups are smaller for the less-differentiated nest, $\mu_{Li} < \mu_D$ for all $i \in \mathcal{L}_H$ since these less-differentiated firms have at least one (Foreign) competitor within $\mathcal{L}$. The consumption of Foreign goods Q_L^* and Q_D^* and the total quantity of labor are the same for the market and the planner by construction of the problem. So, the only way for the right-hand side to be greater than 1 is for $Q_L^M/Q_D^M > Q_L^W/Q_D^W$ and $Q_{LH}^M/Q_L^M > Q_{LH}^W/Q_L^W$. That is, for the market to allocate more labor to the production of less-differentiated goods than to the production of differentiated goods. ■

D Robustness of the Theory

Appendix D.1 introduces free entry and discusses multiplicity of equilibria. Appendix D.2 revisits the results in a model with two symmetric countries, instead of the small open economy in the main text.

D.1 Free Entry

We add a free-entry condition to the general equilibrium model. A large mass of entrepreneurs may pay a fixed cost of f_E units of labor to enter the market. Upon entry, a firm is assigned its own variety, a sector, and a productivity. This condition adds an equilibrium mass of firms M and a corresponding condition that expected profits must equal wf_E:

$$Mf_E = \int_0^1 \left[\sum_{i \in S_H} \mathbf{1}\{c_{iL} \leq c^*(w)\} \pi^*(c_{iL}) + \sum_{i \in \mathcal{D}_H} \pi_D(c_{iD}) + \sum_{i \in \mathcal{L}_S} \pi_L(c_{iL}, \hat{\mathbf{c}}_{-iL}) \right] dS \tag{D.1}$$

Since entry is not directed toward specific sectors, then shocks to a single sector does not affect entry. The results on shocks to a zero-measure firms hold for any fixed set of firms, in particular, the one where the free entry condition is met.

The analysis of a shock to a non-zero mass of firms requires a small modification. A sufficiently large decrease in foreign costs decreases the mass of firms. The shock drives to zero the profit of selling in the domestic market, and so the only remaining term in equation (D.1) would be π^* and the mass of domestic firms together with other equilibrium variables would be determined by domestic productivity relative to foreign demand function. The rest of the proof remains unchanged.

There are a few practical difficulties with free entry. First is in the interpretation of existing firms' responses to decreases in foreign prices. Free entry must not completely reshuffle firms assigning new productivity parameters and eliminating the concept of an existing firm. One way around this issue is to introduce dynamics and allow firms to choose to exit and subject them to random exit shocks. Then in any period and given any shock, expected profits must be less than or equal to wf_E, with equality if entry is positive. Second is that for any measure of entrants, the productivity distributions must be defined so that the assumptions on continuity across sectors in the general equilibrium model hold.

D.2 Two Symmetric Countries

Set up There are two symmetric countries, each with an inelastic supply of labor, with measure one. Labor is the only input in production. It can move freely across firms within countries, but not across countries. The set of sectors is $[0, 1]$. Each country and sector has a finite and exogenous set of firms. The two countries are symmetric in the sense that the vectors of Home and Foreign labor requirements in sectors [0,0.5) is the same as the vectors of labor requirements in (0.5,1], except that Foreign is switched with Home. We describe the economy from Home's perspective.

For simplicity, we maintain the assumption that firms can only export their less-differentiated varieties.[2] Denote firm i's per unit labor requirement with $\tilde{c}_{iL}$ if we the firm is less-differentiated and $\tilde{c}_{iD}$ if it is differentiated. Normalizing wages in both countries to one, the per unit cost of a variety in Home is $c_{iL} = \tilde{c}_{iL}$ and $c_{iD} = \tilde{c}_{iD}$. The unit cost of delivering of delivering each unit of their

[2] As in the small open-economy model, nothing changes if foreign firms sell also in nests $\mathcal{D}^*$ in which Home firms cannot sell.

variety in Foreign is $c_{iL} = \tau\tilde{c}_{iL}$ where $\tau > 1$ is an iceberg cost. We maintain the same assumptions that the number of firms is bounded and that the vector of labor requirements is bounded from below, and it is continuous in all but a finite set of sectors where the number of firms in Home or Foreign changes.

Sectoral Game The game in each sector and market (Home and Foreign) has the following timing. (1) In ascending order of unit cost c_{iL} all firms make their discrete choices. Foreign firms decide whether to sell in Home or not. If they export, they pay a fixed cost f^* units of labor. Home firms decide on whether to (i) exit, (ii) produce a less-differentiated variety, or (iii) produce a differentiated variety. (3) All firms, Home and Foreign, simultaneously set prices.

We consider the subgame perfect equilibrium within a sector-market. The equilibrium is also symmetric in that both countries have wage set to one and the same income and price-index pair $(y, \overline{P})$. We write the general equilibrium conditions when all firms in all sectors play the subgame perfect equilibrium. The pricing rule is the same as in the main text. The price p_L, elasticity of demand ϵ_L, market share s_L, sales x, and profit π_L of a firm i, domestic or foreign, with unit cost c_{iL} selling in the less differentiated nest $\mathcal{L}_S$ in Home are

$$
\begin{aligned}
p_L(c_{iL}, \mathbf{c}_{-iL}) &= \frac{\epsilon_L(c_{iL}, \mathbf{c}_{-iL})c_{iL}}{(\epsilon_L(c_{iL}, \mathbf{c}_{-iL}) - 1)} \\
\epsilon_L(c_{iL}, \mathbf{c}_{-iL}) &= \sigma s_L(c_{iL}, \mathbf{c}_{-iL}) + \eta(1 - s_L(c_{iL}, \mathbf{c}_{-iL})) \\
s_L(c_{iL}, \mathbf{c}_{-iL}) &= \left(\frac{p_L(c_{iL}, \mathbf{c}_{-iL})}{P_{LS}}\right)^{1-\sigma} \\
x_L(c_{iL}, \mathbf{c}_{-iL}) &= \overline{P}^{\eta-1} P_{LS}^{\sigma-\eta}[p_L(c_{iL}, \mathbf{c}_{-iL})]^{1-\sigma} y \\
\pi_L(c_{iL}, \mathbf{c}_{-iL}) &= \frac{x_L(c_{iL}, \mathbf{c}_{-iL})}{\epsilon_L(c_{iL}, \mathbf{c}_{-iL})}
\end{aligned}
$$

where P_{LS} is the equilibrium price index of nest $\mathcal{L}_S$, the less-differentiated nest of sector S, and $\mathbf{c}_{-iL}$ is the vector of unit costs of firm i's competitors in nest $\mathcal{L}$ in the subgame in which firm i does not differentiate and all other firms play their subgame perfect equilibrium strategies. A Foreign firm in sector S exports if $\pi_L(\mathbf{c}_{-iL}, \tau c_{iL}) - f^* \geq 0$. Let the set of firms satisfying this condition in sector S be $\mathcal{L}^*_{FS}$. Foreign total exports to Home are

$$
\int_0^1 \sum_{i \in \mathcal{L}^*_{FS}} x_L(c_{iL}, \mathbf{c}_{-iL}) dS
$$

The discontinuities in set $\mathcal{L}^*_{FS}$ have zero measure since profits are continuous for any set of discrete choices. Then, the integral exists because labor requirements are continuous almost everywhere and bounded away from zero in S.

The set of less differentiated firms in sector S is $\mathcal{L}_S = (\mathcal{L}_{HS} \cup \mathcal{L}^*_{FS})$ where the set of foreign firms exporting $\mathcal{L}^*_{FS}$ is now endogenous. the set of differentiated firms $\mathcal{D}_S$ contains only Home firms by assumption. The set of all nests in the definition of the price index is $\mathcal{N} = \{\mathcal{L}_{SH} \cup \mathcal{D}_S\}_{S \in [0,1]}$ and the price index is

$$\overline{P} = \left\{ \int_0^1 \left[[P_L(\mathbf{c}_{LS})]^{1-\eta} + \sum_{i\in\mathcal{D}_S} \left(\frac{\eta c_{iD}}{\eta - 1} \right)^{1-\eta} \right] dS \right\}^{1/(1-\eta)} \tag{D.2}$$

The representative household gets income from labor and profits:

$$y = w + \int_0^1 \left[\sum_{i\in\mathcal{L}^*_{FS}} \pi_L(\tau\tilde{c}_{iL}, \mathbf{c}_{-iL}) + \sum_{i\in\mathcal{D}_S} \pi_D(\tilde{c}_{iD}) + \sum_{i\in\mathcal{L}_{HS}} \pi_L(\tilde{c}_{iL}, \mathbf{c}_{-iL}) \right] dS \tag{D.3}$$

The first term, summing over set $\mathcal{L}^*_{FS}$, enters Home household income because, by symmetry, the sum of all profits of Foreign firms selling in Home is the same as the profits of Home firms selling in Foreign. A general equilibrium is a set of strategies and a vector $(y, \overline{P})$ such that the strategies are subgame perfect equilibrium strategies in all sectors and equations (D.2) and (D.3) hold.

Welfare. The welfare results remain unchanged since they pertain to the allocation of labor to variable costs and fixed costs (discrete choices) in the domestic market only.

Trade barriers and product differentiation. As in the small open economy, a sufficiently large decrease in foreign prices generally (i) decreases the relative price of less-differentiated varieties, (ii) decreases the overall price index $\overline{P}$. Both of these effects increase differentiation whenever $f_D \leq f_L$. The only issue is that here, foreign prices are endogenous and we cannot directly shock them. A decrease in f^* and τ may not be sufficient to tighten competition in the less-differentiated nets in all sectors due to strategic interactions between firms. In our empirical application, import penetration in China increased substantially, from 14% of GDP in 1998 to 28% in 2006. It is likely to have tightened competition in tradable market segments.