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Escaping import competition in China[☆]

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ABSTRACT

In panel data on Chinese establishments spanning the 2001 WTO accession, import competition is associated with increases in revenue productivity. We propose a model that interprets this (and additional evidence) as firms choosing to differentiate their products to escape import competition. In the model, the profit from endogenous differentiating is decreasing in trade costs and is an inverted U-shaped function of productivity. We estimate the model and study a counterfactual trade liberalization. In response to import competition, firms differentiate their products and increase their markups, thereby increasing revenue productivity as in the data. Since product differentiation is underprovided by the market, the endogenous differentiation increases welfare relative to a model without firms' option to differentiate. So, the model rationalizes the positive relationship between import competition and revenue productivity in the data, and it puts forth a new source of gain from trade.

1. Introduction

At least since Schumpeter's *Theory of Economic Development* (1911), economists have long debated the effects of competition on firm performance and innovation. Numerous trade liberalization episodes in developing countries tightened competition in domestic markets and thereby provided a unique window into this debate. Out of these episodes, a broad consensus emerged among policymakers and trade economists that trade reforms improve the performance of domestic competitors in developing countries. Although this view is mostly supported by empirical work, it has surprisingly little theoretical foundation.[1] If forced to explain, a number of researchers might vaguely resort to "x-inefficiency" or "dynamic gains from trade". Holmes and Schmitz (2010) and Chen and Steinwender (2019) describe theories based on "x-inefficiency" and evidence from case studies in this vein. However, standard theories of international trade contradict the consensus view. Based on increasing returns to scale, Melitz (2003)

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[1] Tybout (2003) surveys studies on the developing countries' trade liberalizations in the 1980s and 1990s, and Shu and Steinwender (2019) survey more recent studies. For productivity, see Pavcnik (2002), Amiti and Konings (2007), Fernandes (2007), Gorodnichenko et al. (2010), Eslava et al. (2013), DeLoecker et al. (2016), and for China, Brandt et al. (2017). Industry case studies include Galdon-Sanchez and Schmitz Jr. (2002), Schmitz Jr. (2005), and Das et al. (2013). Import competition is associated with increased relative demand for skilled workers, itself associated with quality upgrading. See for example Attanasio et al. (2004), Dix-Carneiro and Kovak (2017, 2019) and Topalova (2010), and the surveys by Goldberg and Pavcnik (2004, 2007). R&D is generally too scarce in developing countries, yielding mixed results. For China, see Bombardini et al. (2017) and Liu et al. (2021). This literature is broadly in line with the model's prediction that import competition has an ambiguous effect on revenue productivity and a positive effect on other firm outcomes associated with innovation.

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and its extensions with endogenous innovation predict that tightening competition decreases within-firm productivity by decreasing the scale of production and the rents from innovation.[2]

We propose an extension of Atkeson and Burstein (2008) in which domestic firms respond to reductions in trade costs by innovating to escape foreign competition. We use data on Chinese establishments spanning China's 2001 WTO accession, one of the largest trade liberalizations in history. In the data, tariff cuts are associated with increases in revenue productivity and the introduction of new goods. We estimate the model with pre-liberalization data and use a counterfactual trade liberalization to interpret these data patterns.

In practice, firms escape foreign competition by catering to domestic tastes, offering greater customization, and bundling 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. Not only do small and fuel-efficient cars appeal to Chinese consumers, but it is difficult for firms producing cars abroad to offer customized accoutrements and a wide range of replacement parts because they have long lead times. So, we interpret Chery's strategy as having a non-tradable component.[3]

We model this type of strategy as a shift toward a less exploited market segment insulated from foreign competition. There are two symmetric countries with a continuum of heterogeneous firms. Demand is nested constant elasticity of substitution (CES). The allocation of firms into nests is randomly drawn after each firm chooses whether to produce a more or a less differentiated version of its variety. Differentiation decreases the probability that the firm will have many competitors in its nest. After observing their nests, firms compete à la Cournot.

The incremental profit from differentiation is a non-monotonic function of the firm's productivity. If the firm is unproductive, its profit is small in any nest. If the firm is very productive, it holds near monopoly power in a nest even when it has many competitors. Then, the benefit from further differentiation is small. We assume that firm entry increases the number of firms in less-differentiated nests and has no effect on the number of firms per differentiated nest (more nests are formed). As a result, the entry of foreign firms during a trade liberalization decreases the sales of all firms but disproportionately so in less-differentiated nests. It leads more firms to differentiate as long as differentiation does not require a high fixed cost.

This ambiguity motivates us to estimate the model. We use data on Chinese establishments from 1998 to 2007. During the period, China joined the WTO, average tariffs on manufacturing fell from 18 to 9.4 percent, and imports as a share of GDP doubled from 14 to 28 percent. These tariff cuts are associated with within-firm increases in revenue productivity and the introduction of new goods, even among non-exporting firms.

We estimate the model using cross-sectional data prior to the trade liberalization. We match moments on the joint distribution of sales and revenue productivity. Through heterogeneous markups, the model captures differences across firms in revenue productivity, an estimate of the ratio of marginal revenue to cost.[4]

The model's predictions for China's entry to the WTO depend on the share of firms that are close to indifference between differentiating their products or not. We vary this share across a series of counterfactual simulations of a reduction in trade cost that increases imports as a share of GDP from 14 to 28 percent, the same as in the data. The share of firms differentiating their products increases by 7 to 14 percentage points. The markup of newly-differentiated firms increases substantively in all simulations, but these increases are offset by negative pro-competitive effects on markups. In all, the counterfactual change in revenue productivity ranges from -0.014 to 0.015, compared to 0.032 in the data. In the data and the model, the revenue productivity of small firms increases relative to large firms. The model reduces to Atkeson and Burstein (2008) without the differentiation option. In this special case, the counterfactual change in revenue productivity is -0.042 on average, much smaller than the data and the full model.

The connection between differentiation and markups in the model begs the question of whether differentiation improves welfare at all, and thus whether it justifies policymakers' positive view on import competition. We prove that product differentiation is under-provided by the market. So, the trade-induced product differentiation constitutes a welfare gain from trade not previously identified in the literature. Quantitatively, the gain from trade in the counterfactual decreases by about one third without the differentiation option.

The notion that firms seek market niches insulated from competition, formalized in the model, is common in the business literature (McKenzie and Lee (2008), Porter (2008)) and in interviews with entrepreneurs (Rose (2015)). For the specific case of China, Brandt and Thun (2010, 2016) describe the increased market segmentation during the period of our analysis. Holmes and Stevens (2014) also observe that firms with customized products are more insulated from foreign competition. While their focus is firm size, our model accounts for endogenous product differentiation and markups.[5]

Our theory is most closely related to Aghion et al. (2005, 2015) and Akcigit et al. (2018). There, import competition also spurs innovation by decreasing the profit from inaction, and the gains from innovation are non-monotonic in firm productivity. But in these models, competition comes from less-productive firms, and they are applied to study firms in rich countries facing competition from poor countries. Other mechanisms, such as technology diffusion and offshoring cannot account for all the empirical regularities

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[2] These extensions focus on export expansion and imported inputs, which increase firm size. They include Lileeva and Trefler (2010), Aw et al. (2011), Bustos (2011) and Bøler et al. (2015). In Caliendo and Rossi-Hansberg (2012), improvements in efficiency occur through the reorganization of the firm.

[3] See Farhoomand and Schuetz (2007), Boyd et al. (2008), Teagarden and Fifi (2015), Feng and Wei (2015) for case studies.

[4] Bernard et al. (2003) and Haltiwanger et al. (2018), among others, also use models with variable markups to capture variations in measured productivity. Haltiwanger et al. (2018) estimate that the dispersion in demand elasticities accounts for 80 percent of the dispersion in revenue productivity.

[5] A related mechanism appears in Macedoni et al. (2023): Multi-product firms place their products in market segments taking into account their own costs and market competition. Their application is to cross-sectional patterns in a closed economy, while we focus on responses to foreign competition.

above.[6] The model also relates to previous models of trade with variable markups, e.g., Bernard et al. (2003), Melitz and Ottaviano (2008), and Arkolakis et al. (2017).

The empirical result that output tariff cuts are associated to increases in the revenue productivity of private domestic firms in China is novel.[7] Its focus on import competition complements recent studies on the effect of export opportunities and imported inputs on Chinese firms, e.g., Khandelwal et al. (2013), Handley and Limão (2017), Li et al. (2023), and Liu and Qiu (2016), Brandt et al. (2017).

Section 2 describes the data and motivating facts. The theory is in Section 3 and its results are in Section 4. We estimate the model in Section 5 and perform counterfactual simulations in Section 6. Section 7 checks the robustness of the counterfactual results with respect to the model specification. For example, it introduces wedges to complement variable markups in explaining the dispersion in revenue productivity in the data. Section 8 concludes.

2. Data and evidence

This empirical section serves to motivate the model and to provide an order of magnitude for the effects of import competition on firm behavior against which to benchmark the model. We describe the data in Section 2.1, empirical specification in Section 2.2, results in Section 2.3 and robustness checks in Section 2.4.

2.1. Data sources

We use an annual survey of industrial establishments collected by the Chinese National Bureau of Statistics. The survey comprises private enterprises with annual sales of more than 5 million yuan and all state-owned enterprises (SOE's). 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. See Du et al. (2012), Aghion et al. (2015), and Brandt, Van Biesebroeck, Wang, and Zhang (2017, BVWZ henceforth) for further details.

The original dataset has 2,226,104 establishment-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 establishments with zero foreign ownership and zero state ownership. See Section 2.4 for the results with multinationals and SOE's. The final sample has 1,037,738 observations.

Our tariff data are the World Integrated Trading Solution (WITS), maintained by the World Bank. We use the 2002 Chinese Input-Output table to construct some variables.

2.2. Empirical specification

Our main regression specification is:

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

where the subscripts refer to firm i, year t, and the four-digit sector $j(i,t)$ of firm i in year 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. The independent variable of interest $\text{Output\_Tariff}_{jt}$ is the tariff that China imposes on its imports of sector j in year t.

Sector-time controls X_{jt} include tariffs on sectors upstream (inputs) and downstream from j, state ownership in sector j, and foreign ownership in sector j and in sectors upstream and downstream from j. Firm-time controls X_{it} include zero–one dummy variables indicating whether firm i received subsidies, whether it received a tax holiday, and whether it paid below median interest rates on loans. See Appendix A.1 for details.

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. Following the literature, we instrument for output, upstream, and downstream tariffs using the corresponding tariff for the firm in 1998 interacted with a dummy variable equal to one after China entered the WTO.[8] BVWZ document a strong negative correlation between initial tariffs and changes in tariffs in China, and they confirm that changes in tariffs are not correlated with initial sector characteristics or with trends in establishments (Figure 3 and Table 1 in BVWZ).

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[6] See Sampson (2015), Perla et al. (2021), Buera and Oberfield (2016) for technology diffusion and trade. Offshoring and future export opportunities (also in Perla et al. (2021)) do not explain the correlation between firm outcomes and tariff cuts or the strong empirical results in a subsample with only non-exporting firms. Firms respond to competition by switching specialization in Nocke (2006) and Lim et al. (2019), but competition must come from below to increase firm markups. In Khandelwal (2010) and Medina (2022) firms upgrade quality to escape competition from lower-quality firms.

[7] Our proposed mechanism applies to import-competing firms. Accordingly, most of our analysis excludes state-owned enterprises, which are influenced by political objectives, and foreign multinationals, which are influenced by other markets and may have limited ability to cater to Chinese consumers and couple their products with non-tradable services. When we include these firms (Appendix Table A1, row 1), we find no relation between output tariffs and revenue productivity, consistent with Brandt et al. (2017, 2019) using the same data and similar empirical specification. See also Tables A3 and A4 for the samples with only foreign multinationals and only SOE's respectively.

[8] See Goldberg et al. (2009), Amiti and Konings (2007), and Attanasio et al. (2004). We cannot use the initial tariffs alone as an instrument because our regressions have firm fixed effects.

The main dependent variable y_{it} is total factor productivity–revenue (TFPR). We estimate separately for each two-digit sector the production function

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

where Y is revenue, L is labor, K is the value of capital, M is spending on material inputs, and α_{0j}, α_{Lj}, α_{Kj} and α_{Mj} are parameters to be estimated, separately for each two-digit sector. We deflate revenue and cost variables with the sectoral price indices.[9] 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 2.4. The estimated $TFPR_{it}$ is the predicted value of $\log Y_{it} - \hat{\alpha}_{Lj(i,t)} \log L_{it} - \hat{\alpha}_{Mj(i,t)} \log M_{it} - \hat{\alpha}_{Kj(i,t)} \log K_{it}$. When TFPR is the dependent variable in (1), we add two-digit sector fixed effects.

We do not attempt to estimate markups or decompose TFPR into TFP-quantity and price for two reasons. First, we do not have the necessary data. Methods to estimate markups and TFPQ require data on the mix of products within a firm into finely defined categories as explained in Foster et al. (2008) and De Loecker (2011), and DeLoecker et al. (2016), and data on prices as explained in Bond et al. (2021).[10] Second, the interpretation of TFPQ and standard markup measures can be misleading if goods are differentiated as observed by Foster et al. (2008, 2016), Atkin et al. (2019), and De Roux et al. (2021) among others. TFPR is a broad measure of firm performance that may change with unit costs, distortions in input or output markets, and returns to scale. While our empirical section does not take a stance on the source of variation in TFPR, our theory explains it with heterogeneous markups (and with wedges in Section 7). Haltiwanger et al. (2018) estimate that variable markups account for almost 0.8 of the variation in TFPR.[11]

2.3. *Empirical results*

Panel A of Table 1 reports the coefficients on output tariffs from regression (1) when the dependent variable is revenue productivity. The coefficients are all negative and statistically significant, including in the subsample with only non-exporting firms. The coefficients are larger in absolute value in the IV than in the OLS specifications, possibly due to firms responding more to the large tariff cuts of the WTO accession than to smaller cuts in other years. Using the IV specification with all establishments, a one standard deviation in log of tariffs, around 0.5, is associated with an increase in the firm's revenue TFPR by about 2.5 percent (0.5 × 0.0505).[12]

In Panel B, we change the dependent variable to the share of new products in the firm's sales and to a dummy for whether the firm introduced a new product that year. The coefficients are negative and statistically significant in the IV. A one standard deviation in the log of tariffs 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).

The results in Panel B are only suggestive since the introduction of new products is self-reported by the firm. But they complement the results on revenue productivity because they capture only firm behavior. In contrast, revenue productivity, an estimate of revenue to cost ratio, is also directly affected by market changes in demand and supply as observed by De Loecker (2007).

To investigate whether the responses to tariff cuts differ across firms of different sizes, we repeat the regressions from Panel A of Table 1 replacing log $\text{Output\_Tariff}_{j(i,t)t}$ with its interaction with dummies indicating the firm's quartile of sales within its sector in year $t-1$. We also add these quartile dummies as regressors. Table 2 reports the results. The coefficient on the interaction terms increases with quartile of sales. It is 40 to 160 percent larger in absolute value in the smallest relative to the largest quartile. This difference is statistically significant in most specifications, as the p-value indicates. The smallest quartile has a negative and significant coefficient in all specifications. That is, tariff cuts are associated with increases in revenue TFP that are particularly large among small firms. Although selection may play a role, these results are in line with the heterogeneity in BVWZ and Chen and Steinwender (2019).[13]

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[9] 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 to 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 the total number of employees.

[10] See De Loecker and Goldberg (2014), De Loecker (2021) for methods to estimate markups without price data. The standard assumptions in these methods, monopolistic competition and constant elasticity, do not hold in our model.

[11] Haltiwanger et al. (2018) use data on prices in sectors with relatively homogeneous goods in the United States. Dispersion in revenue productivity arises through variable markups in Bernard et al. (2003) and Haltiwanger et al. (2018), imperfect capital markets in Buera et al. (2011, 2021) and Midrigan and Xu (2014), imperfect labor markets in Berger et al. (2022) and Felix (2021), and returns to scale in Foster et al. (2016) and Haltiwanger et al. (2018).

[12] By comparison, Pavcnik (2002) estimates that revenue TFPR increased by 10 percent more in Chilean firms competing with imports (non-exporters) than in firms producing non-tradables from 1980 to 1986, a period spanning the Chilean trade liberalization. De Loecker (2011) estimates that the removal of quotas in Belgium increases firm productivity by 2 percent.

[13] Appendix Table A8 reports the analogous table when the dependent variable measures the introduction of new goods. The difference between quartiles is less systematic. This asymmetry is consistent with the model, where import competition increases the revenue productivity of small relative to large firms even when small firms do not innovate more than large firms.

Table 1

Regressions of productivity and introduction of new goods on output tariffs.

	Coefficient on output tariffs	Standard error	Number of observations	Specification
Panel A: Dependent variable is revenue productivity				
TFPR, Olley-Pakes	−0.0304***	0.0027	1,037,738	OLS, all firms
TFPR, Olley-Pakes	−0.0505***	0.0169	1,037,738	IV, all firms
TFPR, Olley-Pakes	−0.0617***	0.016	826,072	IV, non-exporters
TFPR, FE	−0.0322***	0.0028	1,037,738	OLS, all firms
TFPR, FE	−0.0477***	0.0184	1,037,738	IV, all firms
TFPR, FE	−0.0580***	0.017	826,072	IV, non-exporters
Panel B: Dependent variable measures the introduction of new goods				
New product share	−0.000356	0.0012	1,037,738	OLS, all firms
New product share	−0.0157**	0.0068	1,037,738	IV, all firms
New product share	−0.00976**	0.0045	826,072	IV, non-exporters
0-1 dummy for new product	−0.000687	0.0029	1,037,738	OLS, all firms
0-1 dummy for new product	−0.0405**	0.0168	1,037,738	IV, all firms
0-1 dummy for new product	−0.0279***	0.010	826,072	IV, non-exporters

The table shows the coefficients on output tariffs from specification (1) where the dependent variable is specified in column 1. All specifications include fixed effects for the firm, year. Other control variables are described in the text and detailed in Appendix A.1. All regressions exclude SOEs and multinationals. The instrument for output tariffs is the initial 1998 tariffs interacted with a WTO dummy. The F-statistic of the first stage is 278 in the full sample and 350 in the sample with only non-exporters. Standard errors are clustered by firm and initial sector. Tariffs and TFPR are in logs. When the dependent variable is TFPR, the regressions also include a fixed effect for two-digit sector and a dummy variable equal to 1 if the firm changes its four-digit sector.

*** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table 2

Responses of firm TFPR to output tariff cuts by quartile of sales.

The dependent variable is TFPR à la Olley-Pakes (OP) 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
Output_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)
Output_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)
Output_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)
Output_tariff × $q4_{i,t-1}$	−0.0240***	−0.0253***	−0.0129	−0.0118	−0.0259	−0.0233
(largest)	(0.00327)	(0.00340)	(0.0168)	(0.0178)	(0.0173)	(0.0182)
H0: tariff × q1 < tariff × q4 (p-value)	0.0006	0.0020	0.041	0.093	0.098	0.169
Observations	701,765	701,765	701,765	701,765	548,283	548,283

The table repeats the results of Table 1 Panel A 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 are in logs.

2.4. Robustness checks and other empirical results

We conduct several robustness checks on Tables 1 and 2. (i) We include multinationals and SOEs in the sample. (ii) We drop the other two tariff measures, upstream and downstream, to check for collinearity and omitted variable bias.[14] To check for selection, (iii) we use a balanced panel of the firms that survived in all ten years of data, and (iv) following Wooldridge (2010), we estimate a survival function and control for the Mills ratio in the main regression. (v) We control for the uncertainty in the United States policy toward its imports from China following Pierce and Schott (2016). (vi) We exclude textiles and apparel, the sectors affected by the expiration of the multifiber agreement (MFA) in the period of our data, and (vii) separately, we exclude computers and peripherals, which experienced a large growth in offshoring. (viii) We include tariffs in the first stage of the TFPR estimation following De Loecker (2007), and (ix) we estimate TFPR following Ackerberg et al. (2015).

Appendix A.2 presents the detailed procedures and results. In all these robustness checks on Table 1, the coefficient on output tariffs is negative and statistically significant in the IV with only non-exporters (firms most affected by import competition), whenever

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[14] Upstream (input) tariffs are correlated with output tariffs and have a positive effect on firm behavior in developing countries, e.g., Goldberg et al. (2009, 2010), Fieler et al. (2018), and in China in particular, Brandt et al. (2017, 2019).

the dependent variable is TFPR or a 0-1 dummy for introducing new goods.[15] In all robustness checks on Table 2, the coefficient on output tariffs increases systematically with quartile of sales. The smallest quartile always has a negative and significant coefficient, but its difference from the largest quartile is not always statistically significant.

Improvements in firm quality are often associated with increases in skill intensity in the literature, e.g., Verhoogen (2008), Khandelwal (2010), and Manova and Zhang (2012). Appendix A.3 presents the results of Table 1 and its robustness checks when the dependent variable is the ranking of sectoral skill intensity. We cannot use firm skill intensity because we only observe the composition of the workforce in 2004. The coefficient is negative and statistically significant in all specifications, associating tariff cuts to switches toward skill intensive sectors. The most common sector switches are toward sectors with a greater scope for differentiation, e.g., from cotton and chemical fibers (1761) to textile and garment manufacturing (1810), and from steel rolling processing (3230) to metal structures (3351). These patterns again are broadly consistent with firms escaping competition through differentiation.

In Table A10, we evaluate other firm outcomes. The IV coefficient with only non-exporters is negative when the dependent variable in specification (1) is a dummy for exit and when it is a dummy for switching sector (at 5 percent significance). It is positive when the dependent variable is accounting profits. These results are consistent with standard theories of international trade, including the model below, where import competition increases the probability of exit and of firms switching sectors, and it decreases firm profits. The coefficient is insignificant when the dependent variable is revenue.[16]

In sum, reductions in Chinese import tariffs are associated with within-firm increases in revenue productivity and with the introduction of new goods. These results cannot be fully explained by offshoring or imported inputs as they are robust to the exclusion of exporting firms and key sectors, and to controls for input tariffs. Next we propose a model where firms differentiate their products to escape foreign competition during a trade liberalization. The model captures revenue productivity, an estimate of a firm's revenue to cost ratio in (2), with variable markups.

3. The model

There are two symmetric countries: Home and Foreign. We describe the model from Home's perspective. Labor is the only input into production. Households supply labor inelastically to a perfect labor market with wages normalized to one.

Households have nested CES preferences. There is an exogenous continuum of firms. The novelty relative to Atkeson and Burstein (2008, AB henceforth) is that we endogenize the allocation of firms into nests. This allocation is stochastically determined after firms make a discrete choice of whether to differentiate their products or not, where differentiation decreases the expected number of competitors in a firm's nest.

In the simplest version of the model, differentiation requires a fixed cost but does not change variable costs. To understand the novel mechanism theoretically, Section 4.1 analyzes this case. For reasons discussed in Section 4.3, in the model below and in the estimation, we allow differentiation to change variable costs.

Timing. First, firms observe their productivity and make their discrete choices of entry and product differentiation. Second, nature aggregates these discrete choices and randomly allocates firms into nests. Third, upon observing their nests, firms set quantities and prices. Last, consumers observe the set of varieties and prices, and decide how much to consume. Firms hire labor, produce and sell their varieties.

Discrete choices and technologies. To sell in Home, each firm i chooses among three discrete choices: (i) to exit, (ii) to produce a less-differentiated variety, (iii) to produce a differentiated variety. Denote these choices respectively with E, L, D. Exiting yields zero profits. The fixed cost f_d is common to all firms, Home or Foreign, that choose $d \in \{L, D\}$ when servicing the Home market. A Home firm i is endowed with a productivity pair (z_{iL}, z_{iD}) that determines its unit cost $1/z_{id}$ if it chooses $d \in \{L, D\}$. A Foreign firm i is endowed with productivity (z^*_{iL}, z^*_{iD}) and its cost of delivering each unit in Home is τ/z^*_{id} where $\tau > 1$ is an iceberg cost. To facilitate the exposition, define $z_{id} \equiv z^*_{id}/\tau$ for a Foreign firm i so that its unit cost of delivering goods in Home is also $1/z_{id}$.

Nature. Firms' discrete choices give rise to a mass of less-differentiated varieties M_L and a mass of differentiated varieties M_D. The number of varieties per nest follows a Poisson distribution with parameter λ_d for $d \in \{L, D\}$. For less-differentiated varieties, the measure of nests $\mathcal{M}_L$ is exogenous and $\lambda_L = M_L/\mathcal{M}_L$. For differentiated varieties, λ_D is exogenous and the measure of nests is endogenous, $\mathcal{M}_D = M_D/\lambda_D$.

With this setting, when more firms enter the market (as in a trade liberalization), the number of firms per less-differentiated nest increases on average, while the number of firms per differentiated nest does not change.

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[15] When the dependent variable is the share of new goods on sales, the coefficient is insignificant in the regression with the United States trade policy and in the balanced panel. Firms that survive all ten years of the sample likely have successful products, with high and stable shares in the firm's sales. To check the hypothesis that younger firms are more flexible to respond to shocks, Table A5 restricts the sample to firms established after 1997. The coefficients on the TFPR regressions are nearly double (in absolute value) the coefficients on Table 1 and A1 (row 3 with the balanced panel).

[16] We also consider sector characteristics. In Table A12, we find no evidence that the TFPR responses are larger in sectors classified by Rauch (1999) as differentiated. These sectors have higher TFPR in the cross-section (Table A11) and hence they may have larger negative pro-competitive effects on markups. See Appendix A.4.3 for the results on richer counties.

Demand. We use the notation $i \in n$ to indicate that firm i is in nest n, and $\mathcal{M}_L$ and $\mathcal{M}_D$ to signify both the measure of nests (as above) and their sets (over which we integrate). The quantity demanded of a variety with price p in nest n is nested CES:

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

where

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

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

and where y is total spending, p_i is the price of variety i and $\mathcal{M} = \mathcal{M}_L \cup \mathcal{M}_D$. The elasticity of substitution between nests is η and between varieties within a nest is σ, where $\sigma > \eta > 1$.

Markups and profits. By backward induction, we first solve the setting of prices and quantities within nests. We omit here firms' discrete choices $d = L, D$ because prices and profits depend only on the *ex post* vector of firm productivity in a nest not on whether this productivity arose from the previous period's decision L or D.

Firms compete à la Cournot. Each firm chooses the quantity that best responds to the quantity of other firms in its nest. As shown by AB, the markup over marginal cost of firm $i \in n$ is $\epsilon_i/(\epsilon_i - 1)$ where

$$\epsilon_i = \left[\frac{1}{\sigma}(1-s_i) + \frac{1}{\eta}s_i\right]^{-1}, \tag{6}$$

$$s_i = \left(\frac{p_i}{P_n}\right)^{1-\sigma}. \tag{7}$$

The elasticity of demand ϵ_i is a weighted harmonic mean between the elasticity within nest σ and the elasticity across nests η, where the weight s_i is the firm's market share in value.

Given the vector of productivity of firms in a nest $\mathbf{z}$, there is a unique vector of elasticity $\boldsymbol{\epsilon}$ and market shares $\mathbf{s}$ that satisfy (6) and (7).[17] Then, we can define a function $P(\mathbf{z})$ as the nest price index (4), and a function $\epsilon(z_i, \mathbf{z}_{-i})$ of the elasticity of demand of a firm with productivity z_i in the same nest as firms with productivity vector $\mathbf{z}_{-i}$. The operating profit from Home sales of this firm is

$$\pi(z_i, \mathbf{z}_{-i}) = \overline{P}^{\eta-1} P(\mathbf{z})^{\sigma-\eta} \left(\frac{\epsilon(z_i,\mathbf{z}_{-i})}{\epsilon(z_i,\mathbf{z}_{-i}) - 1}\right)^{1-\sigma} \frac{z^{\sigma-1} y}{\epsilon(z_i,\mathbf{z}_{-i})} \tag{8}$$

If the firm has no competitors, its profit reduces to $\pi(z_i, \emptyset) = [(\eta-1)\bar{P}z_i/\eta]^{\eta-1} y/\eta$.

Strategies and aggregation. Let $G_d(z)$ be the endogenous cumulative distribution function of productivity parameters z_{id} of the firms that choose $d = L, D$. Denote with $k(m;\lambda)$ the probability mass function of a Poisson distribution with parameter λ.

The aggregate price index is:

$$\overline{P} = \left[\sum_{d\in\{L,D\}} \mathcal{M}_d \sum_{m=1}^{\infty} k(m;\lambda_d) \int_0^\infty \dots \int_0^\infty P(z_1,\dots,z_m)^{1-\eta} dG_d(z_1)\dots dG_d(z_m)\right]^{1/(1-\eta)} \tag{9}$$

The expected operating profit of the firm choosing $d \in \{L, D\}$ with productivity z is

$$\mathbb{E}\pi_d(z) = \sum_{m=0}^{\infty} k(m+1;\lambda_d) \int_0^\infty \dots \int_0^\infty \pi(z,(z_1,\dots,z_m)) dG_d(z_1)\dots dG_d(z_m). \tag{10}$$

where we take the vector of the firm's competitors $(z_1,\dots,z_m) = \emptyset$ when $m = 0$.

Lemma 1. *Assume the* $(\sigma-1)$*th uncentered moments of* G_L *and of* G_D *exist. Then the price index* $\overline{P}$ *exists. For* $d = L, D$*, functions* $\mathbb{E}\pi_d(z)$ *exist, are continuous, strictly increasing and have limits* $\mathbb{E}\pi_d(0) = 0$ *and* $\lim_{z\to\infty}\mathbb{E}\pi_d(z) = \infty$.

The proof is in Appendix B.1.2. A corollary is that there exist unique productivity cutoffs $\underline{z}_d$ such that

$$\mathbb{E}\pi_d(\underline{z}_d) = f_d \qquad \text{for } d = L, D. \tag{11}$$

And there exists a function $\underline{z}_D : \mathbb{R}_+ \to \mathbb{R}$ that gives, for each z_L, the minimum productivity z_D such that the firm chooses D. This function is defined implicitly as $\underline{z}_D(z_L) = z$ where z satisfies

$$\mathbb{E}\pi_D(z) - f_D = \max\{0, \mathbb{E}\pi_L(z_L) - f_L\}. \tag{12}$$

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[17] See proof in Appendix B.1.1.

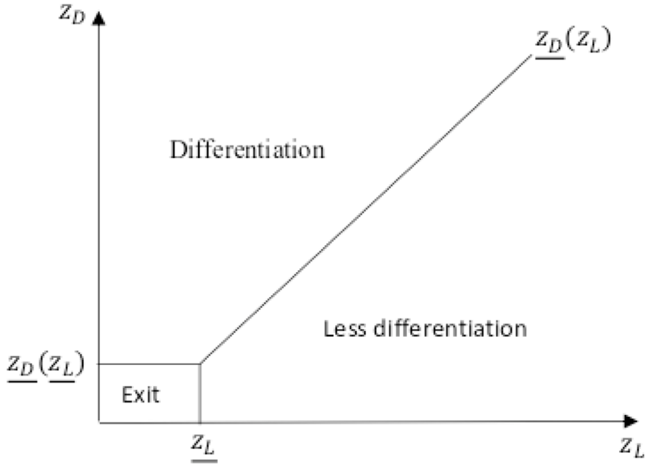

Fig. 1. Example of an equilibrium strategy profile. Note: A firm is a point (z_L, z_D) in the graph. The region where it lies determines its discrete choice.

By Lemma 1, $\underline{z}_D(z) = \underline{z}_D$ if $z \in [0, \underline{z}_L]$, and $\underline{z}_D(z)$ is continuous and strictly increasing if $z \in (\underline{z}_L, \infty)$. The optimal strategy for firm i is:

$$\begin{cases} E & \text{if } (z_{iL}, z_{iD}) \leq (\underline{z}_L, \underline{z}_D) \\ D & \text{if } z_{iD} > \underline{z}_D(z_{iL}) \\ L & \text{otherwise} \end{cases} \tag{13}$$

Fig. 1 illustrates this type of strategy profile. A firm is a point (z_L, z_D) in the graph. The schedules separate the regions of exit, differentiation and less differentiation.

The exogenous set of firms is characterized by a measure M and a cumulative distribution function of productivity parameters $G(z_L, z_D)$. Assume that G has support $\mathbb{R}^2_+$ and a density $g(z_L, z_D)$. Given a strategy profile, the measures of less-differentiated and of differentiated varieties selling in Home are respectively:

$$\begin{aligned} M_L &= M \int_{\underline{z}_L}^{\infty} \int_0^{\underline{z}_D(z_L)} g(z_L, z_D) + g(\tau z_L, \tau z_D) dz_D dz_L \\ M_D &= M \int_0^{\infty} \int_{\underline{z}_D(z_L)}^{\infty} g(z_L, z_D) + g(\tau z_L, \tau z_D) dz_D dz_L. \end{aligned} \tag{14}$$

The cumulative distribution of productivity conditional on choice $d \in \{L, D\}$ is zero if $z \leq \underline{z}_d$. Otherwise, it is respectively for $d = L, D$

$$\begin{aligned} G_L(z) &= \frac{M}{M_L} \int_{\underline{z}_L}^{z} \int_0^{\underline{z}_D(z_L)} g(z_L, z_D) + g(\tau z_L, \tau z_D) dz_D dz_L \\ G_D(z) &= \frac{M}{M_D} \int_0^{\infty} \int_{\underline{z}_D(z_L)}^{z} g(z_L, z_D) + g(\tau z_L, \tau z_D) dz_D dz_L. \end{aligned} \tag{15}$$

Let $\overline{H}$ be the total labor endowment. Households get income from labor and profits:

$$y = \overline{H} + \sum_{d \in \{L, D\}} M_d \left(\int_{\underline{z}_d}^{\infty} \mathbb{E}\pi_d(z) dG_d(z) - f_d \right). \tag{16}$$

3.1. Equilibrium

Let $\mathcal{S}$ be the set of strategies characterized by two cutoffs $(\underline{z}_L, \underline{z}_D) \gg 0$ and a continuous function $\underline{z}_D(z) : \mathbb{R}_+ \to \mathbb{R}_+$ that satisfies $\underline{z}_D(z) = \underline{z}_D$ if $z \leq \underline{z}_L$ and is strictly increasing elsewhere, where firms follow the discrete choice rule in (13). Appendix B.1 proves Proposition 1.

Definition. An *equilibrium* is a strategy $\underline{z} \in \mathcal{S}$, a price index $\overline{P}$ and an income y such that (i) $\underline{z}$ satisfies (11) and (12), (ii) $\overline{P}$ satisfies (9) and (iii) y satisfies (16).

Assumption 1. The cumulative distribution function of productivity parameters $G(z_L, z_D)$ has support $\mathbb{R}^2_+$. Its two marginal distributions, for z_L and z_D, have first and $(\sigma - 1)th$ uncentered moments.

Proposition 1. *Under Assumption 1, an equilibrium exists.*

4. Differentiation, welfare and trade

To highlight the novel mechanism of differentiation and how it differs from standard innovation set ups, we analyze theoretically the special case in which a differentiated firm i is always a monopolist in its nest $\{i\}$. Section 4.1 studies how a firm's profit from differentiation varies with its productivity. Section 4.2 compares these private profits to the social benefit. Section 4.3 discusses the effects of international trade.

4.1. *Profit from differentiation and productivity*

The effect of changes in productivity on the incentives to invest is well known.[18] So, to focus on differentiation, Proposition 2 considers a firm whose productivity does not change with differentiation.

Proposition 2. *In the special case where firms that differentiate become monopolists, the gain from differentiation for a firm with* $z_{iD} = z_{iL} \equiv z$,

$$\mathcal{G}(z) = \mathbb{E}\pi_D(z) - \mathbb{E}\pi_L(z) - (f_D - f_L),$$

is bounded below by $(f_D - f_L)$ *and has limits* $\lim_{z\to 0} \mathcal{G}(z) = \lim_{z\to\infty} \mathcal{G}(z) = f_D - f_L$.

Appendix B.2.1 presents the full proof. Here, to understand the basic intuition, we fix the *ex post* productivity of the firm's competitors $\mathbf{z}$ in its less-differentiated nest. Fig. 2(a) illustrates the non-monotonicity of the net profit from differentiation (a.1) and of the markup (a.2) as functions of the firm's productivity z.[19]

The limit $\mathcal{G}(0)$ follows from Lemma 1. The limit $z \to \infty$ is less trivial because sales go to infinity and the markup difference between L and D goes to zero. Let $p_D = \eta/[(\eta-1)z]$ be the firm's price under differentiation, and P_{-iL} be the CES price index in the less-differentiated nest excluding firm i from the sum. Then

$$\begin{aligned}
\pi(z,\emptyset) &= \frac{y\overline{P}^{\eta-1}}{\eta} p_D^{1-\eta} \\
&\le \frac{y\overline{P}^{\eta-1}}{\eta}\left(P_{-iL}^{1-\sigma} + p_D^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-iL}^{1-\sigma} + \frac{y\overline{P}^{\eta-1}}{\eta}\left(P_{-iL}^{1-\sigma} + p_D^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} p_D^{1-\sigma} \\
&\le \frac{y\overline{P}^{\eta-1}}{\eta}\left(P_{-iL}^{1-\sigma} + p_D^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-iL}^{1-\sigma} + \pi(z,\mathbf{z}).
\end{aligned}$$

The second line is the operating profit of a hypothetical, differentiated firm that charges $\left[P_{-iL}^{1-\sigma} + p_D^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \le p_D$ 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 $\mathbf{z} \neq \emptyset$. Rearranging and taking limits,

$$\lim_{z\to\infty}\left[\pi(z,\emptyset) - \pi(z,\mathbf{z})\right] \le \lim_{p_D\to 0} \frac{y\overline{P}^{\eta-1}}{\eta}\left(P_{-iL}^{1-\sigma} + p_D^{1-\sigma}\right)^{\frac{\sigma-\eta}{1-\sigma}} P_{-iL}^{1-\sigma} = 0.$$

In words, firm i's gain from differentiation is bounded above by the gain from acquiring the residual demand of its competitors in the less-differentiated nest and getting a share $1/\eta$ of it in profits. Since this residual demand goes to zero as the firm's productivity goes to infinity, the gain also goes to zero. So, the gain from differentiation depends on the firm's own sales (when $z \to 0$) and that of its competitors (when $z \to \infty$). The non-monotonic effect of productivity on innovation is reminiscent of Aghion et al. (2005), Aghion and Griffith (2008), and Spearot (2013).

4.2. *Private and social gain from differentiation*

Edmond et al. (2015) study the misallocation of labor in the AB model. Their results hold here for any *ex post* allocation of firms into nests. We focus on the novel allocation of firms into nests through discrete choices.[20] The evaluation of welfare in Proposition 3 assumes that firms are free to re-set prices and variables $\overline{P}$ and y adjust to satisfy (9) and (16) after the described changes in discrete choices.

Proposition 3. *Consider an economy in an equilibrium in which differentiated firms are monopolists in their own nests. Starting from this equilibrium, a planner would strictly increase welfare by reallocating a non-zero set of exiting firms and a non-zero set of less-differentiated firms into the set of differentiated firms. In addition, a planner would strictly decrease welfare if it reallocated any non-zero subset of differentiated firms into the set of either exiting firms or less-differentiated firms.*

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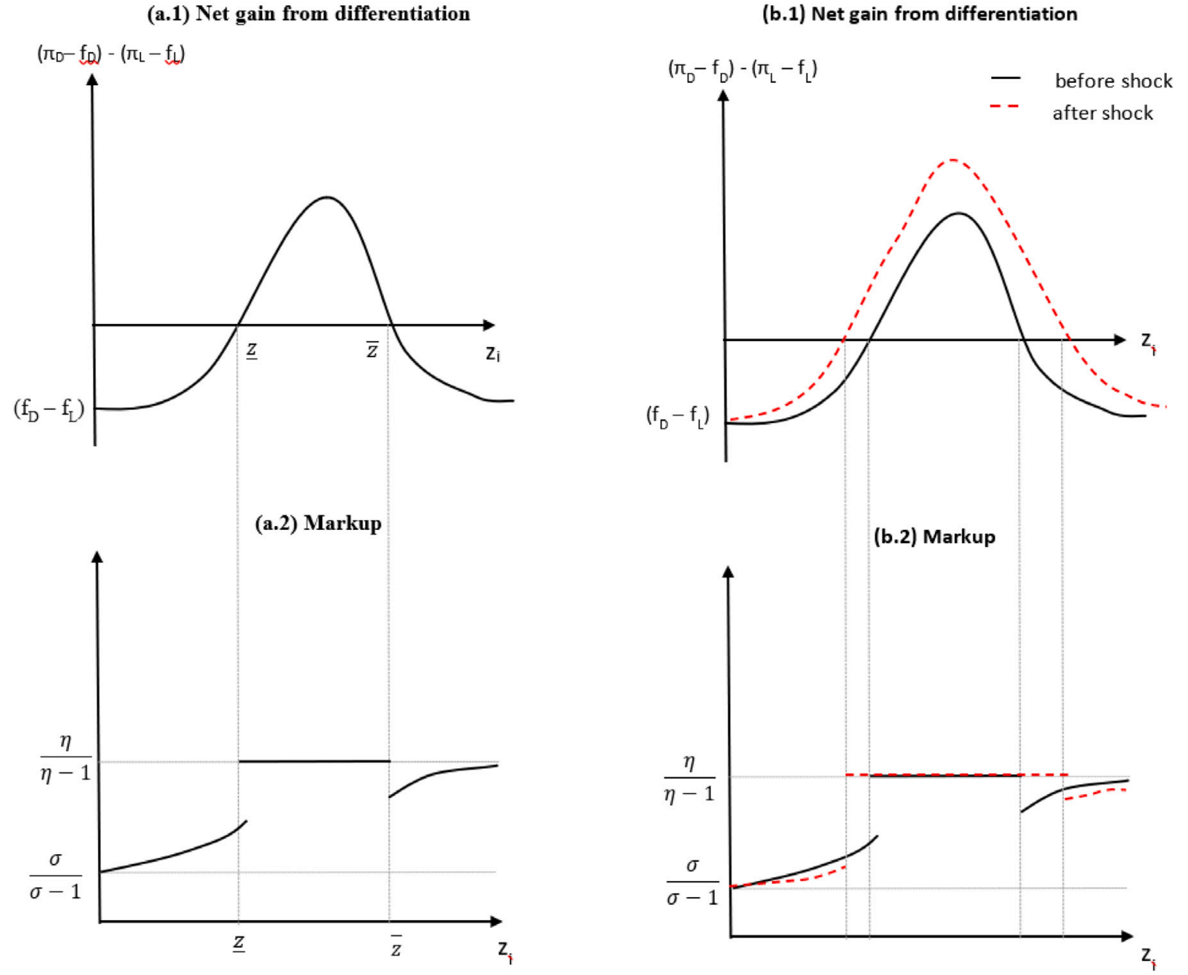
[18] Innovation is often modeled as a fixed cost to increase productivity—e.g., Lileeva and Trefler (2010) and Bustos (2011). Differentiation involves the same considerations if $f_D > f_L$ and $z_{iD} > z_{iL}$.

[19] Appendix B.2.2 proves that the set of productivity z with a positive net profit is convex when the vector of competitors' productivity $\mathbf{z}$ is fixed. Then, the profit from differentiation is an inverted U-shaped function of the firm's own productivity, as in Fig. 2(a). The appendix also considers the cases where $z_{iD} \neq z_{iL}$.

[20] This section is related to the study of optimal variety in Spence (1976a,b), Dixit and Stiglitz (1977) and Dhingra and Morrow (2019). Our approach is closer to Spence (1976a,b) because the other approaches apply only to monopolistic competition.



(a) Productivity, differentiation, and markups **(b) An example of a reduction in trade costs**

Fig. 2. An example of a firm's profit from differentiation and markups as a function of $z = z_{iD} = z_{iL}$, and an example of the effects of a reduction in trade costs. Panel (a) illustrates how the net gain from differentiation and the markup of a firm changes with the firm's productivity (x-axis) when the firm's productivity does not change with differentiation, $z_i = z_{iD} = z_{iL}$, when $f_L < f_D$, and when the vector of its competitors' productivity is fixed. Panel (a.1) illustrates the non-monotonic net gain from differentiation, which arises because the operating profit from differentiation tends to zero as $z_i \to 0$ and $z_i \to \infty$. Panel (a.2) illustrates the markup of the firm given the optimal differentiation in (a.1). Panel (b) illustrates in red the effect of a reduction in trade costs on the firm's net gain from differentiation and markup. In this example, the set of productivity parameters for which the firm differentiates increases (b.1), but the effect on the markup is ambiguous. It decreases in firms that remain less differentiated and increases in firms that switch to differentiation.

A welfare-maximizing planner values differentiation more than the market, but the proposition falls short of the statement that the set of differentiated firms in the market equilibrium is a subset of the planner's solution. The value of a less-differentiated firm (net profit to the firm or welfare to the planner) depends on the whole distribution G_L. Changes in G_L that are not ordered by stochastic dominance may increase the value of less-differentiation for some firms and decrease it for others. To achieve the global optimum from the market equilibrium, the planner will always move some firms into differentiation, but it may also move other firms out of differentiation.

The proof of Proposition 3 is in Appendix B.3.[21] Here, for the basic intuition, we show that welfare decreases marginally when we move a firm from differentiation to exit or to less-differentiation with a known set of competitors' productivity and $f_D \geq f_L$.

Removing a variety from the market, frees up labor to the rest of the economy. The marginal cost of labor is $C = H/Q$ where $Q = y/\overline{P}$ is the aggregate quantity and $H = \overline{H} - M_L f_L - M_D f_D$ is labor allocated for production. Denote with $\mu = \overline{P}/C$ the aggregate markup and with $\mu_D = \eta/(\eta - 1)$ the markup of differentiated varieties.

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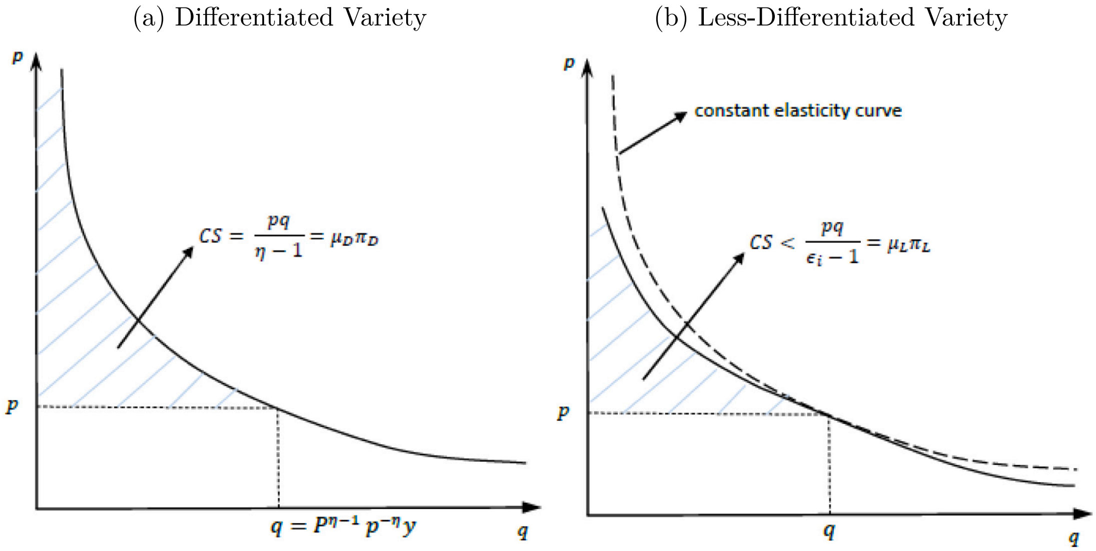
[21] In the general model differentiated firms are not all monopolists in their nests. For this case, Proposition 4 in Appendix B.3 states that the planner values nests more than the sum of profits of the firms in the nest. So, the creation of new nests by differentiation always increases welfare.


(a) Differentiated Variety

(b) Less-Differentiated Variety

Fig. 3. Consumer surplus terms (CS) in Eqs. (17) and (19).
A differentiated firm is a monopolist in its own nest and hence faces a constant elasticity of demand η. As illustrated in Panel (a), the consumer surplus equals its markup times its operating profit. The elasticity of demand of a less-differentiated variety in Eq. (6) is increasing in its price. As illustrated in Panel (b) the consumer surplus is strictly smaller than its markup times operating profit.

By Roy's identity, the value of a differentiated variety i to the planner is:

$$u(z_{iD}, \{i\}) = \overline{P}^{-1} \underbrace{\int_{\mu_D/z_{iD}}^{\infty} q(p, \{i\}) dp}_{\text{consumer surplus}} \quad - \quad C^{-1} f_D \tag{17}$$

$$= C^{-1} \left[\frac{\mu_D}{\mu} \pi(z_{iD}, \emptyset) - f_D \right] \tag{18}$$

where the second line integrates $q(p, \{i\}) = y\overline{P}^{\eta-1} p^{-\eta}$ from (3) and uses $P = \mu C$. Fig. 3(a) illustrates the consumer surplus term.

The demand function that a less-differentiated firm in nest n faces is $q(p, n)$ in (3) where the firm's price p enters into P_n in (4). For firm i, define function $\tilde{q}_i(p) = Ap^{-\epsilon_i}$ where constant A satisfies $\tilde{q}_i(p_i) = q(p_i, n)$ where p_i is its equilibrium price and ϵ_i is the elasticity of demand in (6) at p_i. Fig. 3(b) illustrates $\tilde{q}_i(p)$ with a dashed line and $q(p, n)$ with a solid line. The two schedules intersect at the equilibrium price by construction, and elsewhere, $\tilde{q}_i(p)$ lies above $q(p, n)$, because the elasticity of demand in (6) is strictly increasing in the firm's price. Denote the firm's markup with $\mu_L(z_{iL}, \mathbf{z}_{-i}) = \epsilon(z_{iL}, \mathbf{z}_{-i})/[\epsilon(z_{iL}, \mathbf{z}_{-i}) - 1]$. The firm's contribution to welfare satisfies

$$u(z_{iL}, n) \leq \overline{P}^{-1} \underbrace{\int_{p_i}^{\infty} q(p', n) dp'}_{\text{consumer surplus}} - C^{-1} f_L \tag{19}$$

$$\leq \overline{P}^{-1} \int_{p_i}^{\infty} \tilde{q}_i(p') dp' - C^{-1} f_L \tag{20}$$

$$= C^{-1} \left[\frac{\mu_L(z_{iL}, \mathbf{z}_{-i})}{\mu} \pi(z_{iL}, \mathbf{z}_{-i}) - f_L \right]. \tag{21}$$

The first inequality holds because, when variety i exits, the consumer's valuation of other varieties in nest n increases. The second inequality is the area between q and $\tilde{q}$ in Fig. 3(b).[22] Both inequalities are strict if $n \neq \{i\}$.

With $\mu_D > \mu$ and $\mu_D > \mu_L(z_{iL}, \mathbf{z}_{-i})$, inequalities (18) and (21) together imply that the marginal social benefit of a differentiated variety is always greater than the private profit, whether the comparison is to exit or less differentiation when $f_D \geq f_L$. Compared to exit, the social benefit of a less-differentiated variety is smaller than the private profit if the firm is sufficiently less productive than its competitors for $\mu_L(z_{iL}, \mathbf{z}_{-i}) < \mu$.

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[22] The area under this dashed line is

$$\int_{\mu_{iL}/z_{iL}}^{\infty} Ap^{-\epsilon_i} dp = \frac{A(\mu_{iL}/z_{iL})^{-\epsilon_i+1}}{\epsilon_i - 1} = \frac{\mu_L(z_{iL}, \mathbf{z}_{-iL})/z_{iL}[q(\mu_{iL}/z_{iL}, n)]}{\epsilon - 1} = \mu_L(z_{iL}, \mathbf{z}_{-iL})\pi(z_{iL}, \mathbf{z}_{-iL}).$$

In words, there are two reasons for the planner to value differentiated varieties more than the market. First, less-differentiated varieties steal business from each other (inequality (19)). Second, the area of the consumer surplus in Fig. 3 decreases with the elasticity of demand because consumers value more varieties without close substitutes. This elasticity is lower for differentiated than less-differentiated firms at the point of consumption (reflected in the ratio of markups in (18) and (21)), and it further increases with price for the less-differentiated firms (inequality (20)).

4.3. Effects of international trade: A discussion

In general, a decrease in trade costs τ decreases $\overline{P}$ and the common demand shifter $\overline{P}^{\eta-1}y$ in (3). Low-productivity domestic firms exit, while Foreign firms close to the exporting cutoffs $\underline{z}_L^* = \underline{z}_L\tau$ or $\underline{z}_D^* = \underline{z}_D\tau$ enter. These effects are standard.

There are two opposing effects of the shock on differentiation. First is an overall market size effect. The decrease in $\overline{P}^{\eta-1}y$ decreases all profits and thereby decreases the incentives to differentiate if $f_D > f_L$. Second is a relative effect. The entry of Foreign firms increases the ratio of profits $\pi(z_D, \emptyset)/\mathbb{E}\pi_L(z_L)$ for any z_L and z_D, because by assumption, entry increases the set of differentiated nests, but not the set of less-differentiated nests. Which of these opposing forces prevails depends on the magnitude of the fixed and variable costs of differentiation, $(f_D - f_L)$ and z_{iL}/z_{iD}. It is then important for the estimation to allow for two dimensions of firm productivity (z_{iL}, z_{iD}) and to identify these fixed and variable costs of differentiation.

The effect of import competition on markups is also ambiguous. It increases for firms that differentiate and decreases for firms that remain less-differentiated. For any two *ex ante* less-differentiated firms that make the same discrete choice *ex post*, the markup of the initially smaller firm increases relative to the larger firm.[23] Intuitively, the smaller firm's markup is closer to the lower bound $\sigma/(\sigma-1)$ and therefore responds less to Foreign competition. Panel (b) of Fig. 2 above illustrates the effect of trade on the gain from differentiation and on the markup. In the example, trade increases the set of firms differentiating in Panel (b.1) but has a mixed effect on markups in Panel (b.2).

This example may explain why the effects of trade on TFPR are mixed in the empirical literature.[24] In contrast to this literature and to Table 1, standard models of trade with variable markups, including AB, predict that markups unambiguously decrease within firms that do not export.[25] The proposed model has these same negative pro-competitive effect on markups, but it adds flexibility to these models with the differentiation option. Its predictions regarding trade and markups depend on specific parameters. Next we estimate the model using a pre-WTO cross-section of Chinese establishments, evaluate the ability of the model to replicate the observed change in revenue productivity and introduction of new goods in Tables 1 and 2, and compare it to the AB model.

5. Estimation of the model

The estimation procedure is here and the results are in Section 5.1. We fix some parameters and estimate the remaining with the method of simulated moments.

Parametrization. The distribution of firm productivity (z_L, z_D) follows a bivariate log-normal with mean parameters $a_L = 0$ and a_D, and variance parameters v_L and v_D. As explained below, we cannot identify the correlation parameter ρ. We set $\rho = 0$ initially and experiment with different correlations in the counterfactual. Assume that the distribution of (z_L, z_D) is the same for Foreign and Home firms.[26] The total mass of firms is 1, with a Foreign share of 0.14, corresponding to the ratio of imports to GDP in China prior to its accession to the WTO.

We set the demand shifter $\overline{P}^{\eta-1}y = 1$ by judiciously picking the labor endowment. We do not observe firms that enter the market and exit without producing. We set $f_L = 0.006$ so that about two percent of firms exit.

There are eight parameters left to estimate $\Upsilon = \{\eta, \sigma, a_D, v_L, v_D, \lambda_L, \lambda_D, f_D\}$, where η and σ govern the elasticity of demand, a_D, v_L and v_D govern the distribution of productivity, f_D is the fixed cost of producing a differentiated variety, and λ_L and λ_D govern the distribution of firms into nests. We impose $\lambda_D < \lambda_L$ without loss of generality.

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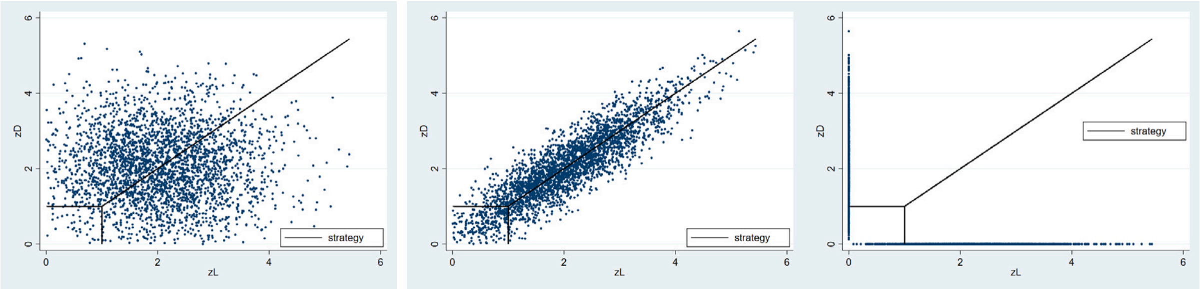
[23] See Proposition 1 in Amiti et al. (2014). The result here holds in expectation comparing firms with different z_L's or *ex post* for two firms with the same set of competitors.

[24] See for example the surveys of Tybout (2003) and Chen and Steinwender (2019).

[25] See Arkolakis et al. (2017) for a general set up of these models.

[26] This assumption, a departure from the theory where the distribution of Foreign firms endogenously depends on τ, simplifies the analysis in two ways. First, in the estimation, we do not need to keep track separately of domestic and foreign firms when calculating moments. Second and most important, it is the simplest way of decreasing the relative price of less-differentiated nests in the counterfactual. Trade increases the set of foreign firms in less-differentiated nests and increases the set of differentiated nests. Conversely, a decrease in τ without much entry tightens competition similarly in less-differentiated and differentiated nests. Appendix D.3 presents a detailed discussion and the example of an economy where foreign and domestic firms compete in separate differentiated nests. We show that the example yields predictions similar to the benchmark below in the cross section and the counterfactual when we simulate a decrease in iceberg costs. Hence, the simplifying assumption here is not necessary for the results.



(a) No correlation $\rho = 0$ (b) High correlation $\rho = 0.9$ (c) Exogenous types L, D

Fig. 4. An illustration of the problem of identifying ρ.

Simulation. We construct a vector, Z with 51 points uniformly distributed between $[0.1, 3]$ and use the same vector for z_{iL} and z_{iD}. The grid of (z_{iL}, z_{iD}) is $Z \times Z$. We limit the size of nests to 1 to 4 firms by truncating the Poisson distribution of firms into nests.

We simulate the model for each guess of parameters Υ. Given η and σ, we get the elasticity and market shares in (6) and (7) for each possible set (nest) of z's in Z with four of fewer elements. There is a total of 341,054 nests with 1,337,985 distinct firm outcomes. We save their markup, profits, and sales. Given a_D, υ_L, υ_D, we calculate the probability mass function of firms in the grid $g(z_L, z_D)$ for all $(z_L, z_D) \in Z \times Z$.

We then iterate over strategies to find the equilibrium. For each strategy, we calculate the distribution of productivity conditional on choice $G_d(z)$ in (15). We calculate expected profits $\mathbb{E}\pi_d(z)$ in (10) using $G_d(z)$, the 1.3 million simulated profits, and the grouping of firms into nests implied by λ_d. We use expected profits to update strategies and iterate until (11) and (12) hold.

We calculate the model moments using the simulated 1.3 million firm sales and markups and their probability implied by the parameter estimates and equilibrium strategies.

In Appendix C, we detail this simulation procedure and discuss alternative approaches, on the grid Z and the number of firms per nest.

Moments. We use the 1999 cross-section. We demean all variables in the data by two-digit sector as the model is intended to capture competition across firms within sectors. The eleven moments, in Table 4, describe the joint distribution of sales and TFPR. From the distribution of log of sales, we match the standard deviation and the ratio of the 90th to the 10th percentile (2 moments). From the distribution of TFPR, we match the 10th, 25th, 50th, 75th, 90th percentiles (5 moments). From the joint distribution, we match the mean TFPR by quartile of sales (4 moments).

TFPR in (2) is an estimate of the log of the ratio of marginal revenue to marginal cost. In the model, this ratio equals the log of markups.

Identification. The separate identification of the set of firms that choose L or D is analogous to the identification of latent types in labor models. Differentiated firms are those that have high markup relative to their size.[27] In the model with only one type of firm, say L, small and large firms compete in the same nests. As a result, this special case cannot reconcile a large spread in the distribution of sales with a low correlation between sales and TFPR (see Table 4).

While all parameters are estimated jointly, some moments and parameters are more closely linked. Elasticity parameters η and σ impose upper and lower bounds on TFPR ($\log[\eta/(\eta-1)]$ and $\log[\sigma/(\sigma-1)]$), and the number of firms λ_L and λ_D in each nest governs the distribution of TFPR within these bounds. The variance parameters υ_L and υ_D capture the spread of sales in the data. The fixed cost captures the overlap in the distributions of sales. If f_D is high, then small firms are all less-differentiated and have low TFPR.

With cross-sectional data only, our estimation cannot identify the correlation ρ between draws of z_{iL} and z_{iD}. Data on the cross-section provide information on productivity z conditional on choice, $G_L(z)$ and $G_D(z)$, and only impose bounds on the productivity z_{iL} for firms that choose D and on z_{iD} for firms that choose L.[28] To illustrate this point, Fig. 4 plots three distributions $G(z_L, z_D)$ that deliver exactly the same distributions $G_L(z)$ and $G_D(z)$, and hence the same cross-sectional moments on revenue and TFPR. The correlation between z_{iL} and z_{iD} is 0 in Panel (a) and 0.9 in Panel (b), and in Panel (c) firms either have $z_{iL} = 0$ or $z_{iD} = 0$.

The three economies in Fig. 4 differ in firms' responses to shocks. In general, firms are more responsive to shocks in Panel (b) than in Panel (a), where few firms are close to indifference between L and D. In Panel (c), L and D are exogenous firm types. We estimate the model with $\rho = 0$, but when simulating the counterfactual trade liberalization in Section 6, we change this correlation by moving firms closer or farther from the estimated strategy schedule $\underline{z}_D(z_{iL})$.

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[27] See Keane et al. (2011) for the identification of latent types and unobserved state variables in labor. This identification strategy gives another reason why we cannot set $z_{iL} = z_{iD}$ for all i. The separate identification of L and D firms requires a sufficient overlap in firm sales across the two types, which does not occur if $z_{iL} = z_{iD}$. This special case overestimates the correlation between sales and TFPR similar to the model with only one type in Table 4.

[28] This lack of identification is analogous to the problem of identifying the productivity of workers in occupations that they did not choose but may move to in response to shocks in Roy models. See Heckman and Honore (1990) and French and Taber (2011).

Table 3
Parameter estimates.

Parameter description		Estimate	Std. error
Elasticity of substitution between nests	η	1.59	0.01
Elasticity of substitution varieties within nests	σ	8.76	0.44
Mean log z_D	a_D	−1.87	0.04
Variance log z_L	υ_L	0.18	0.02
Variance log z_D	υ_D	0.20	0.02
Poisson parameter of distribution of firms into L nests	λ_L	12.91	0.35
Poisson parameter of distribution of firms into D nests	λ_D	7.53	0.17
Fixed cost of differentiated varieties	f_D	0.0058	0.0002

Table 4
Fit of the model.

	Data	Model	Model with only L firms
Distribution of log sales			
Std deviation	1.22	1.24	0.32
90/10 ratio	2.97	2.96	1.01
Distribution of revenue productivity (TFPR)			
10th percentile	−0.28	−0.21	−0.20
25th percentile	−0.14	−0.16	−0.20
50th percentile	−0.003	−0.05	−0.11
75th percentile	0.14	0.10	0.07
90th percentile	0.29	0.27	0.29
Mean TFPR by quartile of sales			
Q1	−0.20	−0.19	−0.18
Q2	−0.05	−0.06	−0.15
Q3	0.05	0.04	−0.10
Q4 (largest)	0.20	0.21	0.42

Note: We demean log sales and revenue TFPR in the model and by two-digit sectors in the data. The parameter estimates (std. errors) of the model with only L firms are: $\eta = 1.28$ (0.005), $\sigma = 13.58$ (1.92), $\upsilon_L = 0.27$ (0.011), and $\lambda_L = 7.36$ (0.010).

5.1. Estimation results

Table 3 presents the parameter estimates. The parameters are well identified and have small standard errors.[29] The elasticity of demand, $\eta = 1.59$ and $\sigma = 8.76$, is in line with the literature.[30] The estimates $\lambda_L = 12.9$ and $\lambda_D = 7.5$ imply that the average number of firms is 3.1 in D nests and 3.5 in L nests.

The means of the log of productivity are $a_D = -1.87$ and $a_L = 0$ (normalized). Although the difference in productivity conditional on choice is less than a_D, differentiated firms are generally smaller than less-differentiated firms, as in Holmes and Stevens (2014). The fixed cost $f_D = 0.0058$ (s.e. 0.0002) is close the value set for $f_L = 0.006$. With a small $(f_D - f_L)$, the model captures the presence of many small firms with high TFPR, a salient feature of the data. In the model, these are the firms with low productivity z_{iL} and z_{iD}, but relatively high z_{iD}/z_{iL}. For most firms, z_{iD}/z_{iL} is low, and as a result, 80 percent of surviving firms choose less-differentiation.

The aggregate elasticity of demand for foreign varieties with respect to trade costs τ is 3.09. The trade elasticity is slightly higher, 3.30, with entry. It barely changes with the discrete choice between L and D, because the choice depends mostly on the ratio $z_{iL}/z_{iD} = (z^*_{iL}/\tau)/(z^*_{iD}/\tau)$ since $f_D \approx f_L$. So, the difference in welfare results between the counterfactual simulations below, with and without product differentiation, does not stem from a difference in trade elasticity. The trade elasticity 3.30 is close to the median 3.19 in the survey by Head and Mayer (2014) (their Table 3.5).

Table 4 shows the fit of the model for the targeted moments. The model captures the standard deviation and ratio of 90th to the 10th percentile of the log of sales. It captures the distribution of TFPR well, except that it overestimates the 10th percentile. It also captures well the mean TFPR by quartile of sales. The last column shows the special case with discrete choices E and L only. As previously explained, this special case underestimates the spread in sales and overestimates the correlation between log of sales and TFPR. This correlation (not directly targeted) is 0.66 in the data and in the full model, and 0.89 in this special case.

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[29] We follow Davidson et al. (2004) chapter 9 to estimate standard errors. For the variance of the moments, we randomly draw with replacement 1,000 sets of 100,242 firms and recalculate moments.

[30] By comparison, Edmond et al. (2015) set $\eta = 1.28$, Eaton et al. (2013), Amiti et al. (2019) and Gaubert and Itskhoki (2021) set $\eta = 1$. Our larger η is consistent with our interpretation of nests as segments of market within sectors while these other papers interpret nests as sectors. Similarly, $\sigma = 8.76$, the elasticity of substitution across Chinese varieties within segments, is larger than the elasticity across varieties from different countries in Broda and Weinstein (2006) (mean 4.0 for SITC-3).

Table 5
Summary of counterfactual outcomes for Home firms when selling in home.

	Data (1)	No differentiation (2)	Few firms at margin (3)	Small firms at margin of diff. (4)	More firms at margin of diff. (5)
Correlation $\log z_{iL}$, $\log z_{iD}$		$z_{iL} = 0$ or $z_{iD} = 0$	0	0.63	0.86
Panel A: Changes in TFPR (data) and in log markups (model), surviving firms					
Mean	0.032	−0.042	−0.014	0.015	0.014
By initial quartile of sales ↓					
1	0.021	−0.005	0.007	0.016	0.007
2	0.018	−0.018	0.003	0.022	0.013
3	0.006	−0.041	−0.005	0.028	0.032
4	0.008	−0.094	−0.058	−0.007	−0.003
Panel B: Introduction of new goods (data) and shifts from L to D (model)					
Mean	0.026	–	0.074	0.143	0.138
By initial quartile of sales ↓					
1	0.033	–	0.156	0.236	0.210
2	0.022	–	0.077	0.182	0.146
3	0.019	–	0.046	0.121	0.124
4	0.017	–	0.016	0.032	0.067
Panel C:					
Exit	0.041	0.066	0.053	0.000	0.000
Welfare: $(y_1/\overline{P}_1) \times (\overline{P}_0/y_0) - 1$		0.084	0.144	0.205	0.208
Aggregate markup: μ_1 - μ_0		−0.043	−0.025	−0.001	0.006

6. A counterfactual trade liberalization

We perform several simulations of a counterfactual trade liberalization. In all of them, we hold the mass of domestic firms fixed and increase the mass of Foreign firms relative to all firms from 0.14 to 0.28, respectively equal to imports as a share of Chinese GDP in 1998 and 2007. We numerically calculate the new equilibrium, maintaining $\lambda_D = 7.53$ at its estimated level and judiciously increasing λ_L to maintain the measure of less-differentiated nests $\mathcal{M}_L$ constant.[31] Recall that this assumption from Section 3 implies that foreign entry disproportionately tightens competition in less-differentiated nests. The simulations vary according to the share of firms close to the margin of indifference between differentiating their products or not, as in Fig. 4. All simulations have the same predictions for the cross section as the estimated model and the same trade shares before and after the shock.

Table 5 summarizes the results. For comparison, column (1) has the predictions from the data under the assumption that the general equilibrium effects of trade are similar to the effect of trade in sectors with larger tariff cuts relative to other sectors.[32] From 1998 to 2007, the average log change in tariffs across sectors was −0.64. The first column of Table 5 multiplies this number by the coefficients (IV all firms) of Tables 1 and 2, and Appendix Tables A8 (for new goods by quartile of sales) and A10 (for exit).

The model simulations are in columns (2) through (5). In column (2) firms do not switch between L and D, because their productivity is positive only in their original choice $d \in \{L, D\}$, as in Panel (c) Fig. 4. This case reduces the model to AB where the allocation of firms into nests is exogenous. By assumption, firms do not change their varieties (Panel B) and tighter competition is the only effect on markups (Panel A). Competition tightens in less-differentiated nests more than when domestic firms can escape through differentiation. The predicted change in TFPR, −0.042, is large and has the opposite sign of the data, 0.032.

In column (3) is the estimated model with $\rho = 0$. The counterfactual increase in foreign competition decreases the demand shifter $\overline{P}^{\eta-1} y$ by 9 percent thereby decreasing the profits from Home sales for all domestic firms. In addition for less-differentiated firms, the average nest size increases from 3.48 to 3.63. In response, 5.3 percent of firms exit and 7.4 percent differentiate their products. In the data, 4.1 percent of firms exit the survey and 2.6 percent report introducing new products. The latter figure probably underestimates differentiation because it does not include re-marketing, quality upgrading, or coupling products with more and improved services.

In the counterfactual, the markups increase for the 7.4 percent of firms that differentiate, by 0.37 unweighted and 0.054 weighted by sales (all in logs). But this increase is not enough to offset the decrease in the markups of firms that remain in less-differentiated nests, 71 percent of firms. The average change in TFPR, −0.014, is closer to the data than column (2) but still negative. In the data and in the model, the TFPR of firms in the *ex ante* smallest quartile of sales increases relative to the *ex ante* large firms.

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[31] See Appendix C.2 for details. The simulation changes spending y through general equilibrium. We also experimented with maintaining y fixed and changing the labor supply under the interpretation that manufacturing is a small share of the economy. The results change very little because the counterfactual simulations here predict only a small change in y (less than 3 percent). The drop in profits from Home sales is mostly offset by an increase in the profits of sales in Foreign with the symmetry assumption.

[32] The model has only one sector. If we add more sectors and make spending in each sector fixed Cobb–Douglas shares, then the entry of foreign firms into a single sector would have the same positive predictions as the baseline counterfactual. The welfare predictions would be proportional to the sectoral Cobb–Douglas share.

In column (4), we increase z_D to the margin of differentiation for less-differentiated firms with a low z_L (in the bottom half of the distribution). The model then predicts an increase in markup of 1.4 log points, much closer to the data's 3.2 log points. When we move small and large firms closer to the margin in column (5), small firms differentiate less than in column (4) because the probability of facing large competitors in differentiated nests increases. Since smaller firms are the ones with a greater scope for increasing markups (see Section 4.3), the average markup increase within firm is 1.4 log points, slightly smaller than in column (4). The total share of firms differentiating is 14 percent in columns (4) and (5).

As anticipated, the welfare gains from trade increase with the number of firms that differentiate. Real wage changes range from 8.4 percent in the column (2) (AB model) to 20 percent in columns (4) and (5).[33]

In sum, firms in the model respond to a counterfactual increase in import competition by switching to less-exploited market niches. This response is in line with firms' introduction of new goods in the data. Firms that escape competition in the model increase their markups. The extent to which this increase offsets standard, negative effects of competition on markups depends on how many firms, especially how many small firms, are close to the margin of differentiation. Compared to the model without the novel option to differentiate, the full model predicts changes in revenue productivity that are closer to the data, and higher welfare gains from trade.

In all scenarios considered, the model underestimates the changes in revenue productivity in the data, and the literature offers little guidance to fill this gap. Empirically, the quality of data and methods to measure firm performance are still evolving. Theoretically, x-inefficiency and agency problems within firms could play a role. There could also be interactions between international trade and the various sources of dispersion in revenue productivity proposed recently (cited in Section 7.1 below).[34]

7. Extensions and alternative specifications

To better understand the results and their robustness, we present alternative specifications of the model. For each specification, we re-estimate the model and repeat the four counterfactual simulations of Table 5. Table 6 summarizes these counterfactual results. Details of the new specifications and estimation results are in Appendix D.

7.1. Introducing wedges

In the proposed model, revenue productivity differs across firms only through variable markups. But the literature presents many other mechanisms, such as imperfect capital markets (Buera et al. (2011, 2021), Midrigan and Xu (2014)), imperfect labor markets (Berger et al. (2022) and Felix (2021)) or returns to scale (Foster et al. (2016), Haltiwanger et al. (2018)). Here, similar to Hsieh and Klenow (2009), we introduce wedges in the form of labor taxes redistributed to households lump sum.

Assume each firm is endowed with its productivity pair (z_{iL}, z_{iD}) and a pair of wedges (t_{iL}, t_{iD}). The unit cost of production of firm i, when it chooses $d \in \{L, D\}$, is $(1 + t_{id})/z_{id}$ where $1/z_{id}$ is the labor cost and t_{id}/z_{id} is a tax on labor. The behavior of a firm within its nest depends only on the productivity adjusted for wedges, $\tilde{z}_{id} = z_{id}/(1 + t_{id})$, of itself and of its competitors.

Measurement. We omit the firm's discrete choice d from the subscripts. With wedges, markups and TFPR differ. Firm i's markup is its price over marginal cost:

$$\mu_i = \frac{p_i}{1/\tilde{z}_i} = \frac{\epsilon(\tilde{z}_i, \tilde{\mathbf{z}}_{-i})}{\epsilon(\tilde{z}_i, \tilde{\mathbf{z}}_{-i}) - 1}$$

Firm i's TFPR is the log of price over the marginal product of labor (there is no capital in the model):

$$TFPR_i = \log \frac{p_i}{1/z_i} = \log \frac{p_i(1 + t_i)}{1/\tilde{z}_i} = \log(\mu_i) + \log(1 + t_i) \tag{22}$$

Estimation procedure with wedges. An identification issue arises here. Firm sales in the model depend on adjusted productivity $z/(1+t)$ and TFPR in Eq. (22) depends only on $1 + t$. Hence, with a sufficient flexible parametrization of wedges t and productivity z, the model can perfectly match the targeted moments on the joint distribution of sales and TFPR—even if markups were constant and there were no discrete choices as in Hsieh and Klenow (2009). We deal with this issue by choosing the share of the variance in TFPR across firms that is accounted for by markups. We estimate the model with wedges twice, once setting $V(\log \mu_i)/V(TFPR_i)$ to 0.75 and once to 0.50. Haltiwanger et al. (2018) estimate this share to be 0.8. The other moments are the same as before.

We assume that the distributions of t_{iL} and of t_{iD} are identical and independent of each other and of (z_{iL}, z_{iD}). The cumulative distribution function of $u = 1/(1 + t)$ is u^{β} for $u \in [0, 1]$, where $\beta > 0$ is an added parameter. The baseline model without wedges has $\beta = \infty$ and $V(\log \mu_i)/V(TFPR_i) = 1$.

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[33] These gains are larger than standard trade models but in line with the gains in the AB model (see for example Table 6 in Edmond et al. (2015)). Like other simulations o f the AB model, the elasticity of substitution between large firms' here is small (close to $\eta = 1.59$).

[34] For example, Artuç et al. (2010), Felix (2021), and Leibovici (2021) study how the effects and welfare gains from trade change in the presence of failures in labor or financial markets. Although these failures may give rise to dispersion in TFPR, these papers do not study the implications of trade on TFPR.

Table 6
Summary of counterfactual with alternative model specifications.

		Model with wedges		Skill-int. as	Foreign firms can	
	Baseline	$\frac{V(\mu_i)}{V(TFP_i)} = 0.75$	$\frac{V(\mu_i)}{V(TFP_i)} = 0.50$	proxy for D	only choose L	Bertrand
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted change in TFPR, avg. within firms (data = 0.032)						
No differentiation	-0.042	-0.029	-0.029	-0.029	-0.046	-0.044
Correlation $(z_{iL}, z_{iD}) = 0$	-0.014	-0.006	-0.005	-0.018	-0.010	-0.010
Small firms close to margin	0.015	0.010	0.010	0.032	0.007	0.016
All firms close to margin	0.014	0.000	-0.005	-0.002	0.004	0.014
Predicted switches L to D as a share of firms (new goods in data = 0.026)						
No differentiation	–	–	–	–	–	-
Correlation $(z_{iL}, z_{iD}) = 0$	0.074	0.073	0.078	0.046	0.123	0.077
Small firms close to margin	0.143	0.101	0.117	0.202	0.175	0.136
All firms close to margin	0.138	0.084	0.089	0.114	0.158	0.130

Note: Each column presents the results of a different model specification. For each specification, we repeat the four counterfactual simulations in columns (2)-(5) in Table 5. The baseline is the same as Table 5.

Results with wedges. The estimated parameters are in Appendix Table A13. The Poisson parameters governing the number of firms per nest (λ_D, λ_L) increase from (7.5, 12.9) to (13.4, 16.7) and to (13.3, 19.3) when $V(\log \mu_i)/V(TFPR_i)$ equals 0.75 and 0.50 respectively. The number of firms per L and D nest increases, and the variance in markups decreases so that TFPR can be partly explained by wedges. The fit of the model in Table A14 remains similar to Table 4, except that the model with wedges better captures the lower tail of the TFPR distribution.

The counterfactual results in Table 6 are similar between the cases $V(\log \mu_i)/V(TFPR_i)$ equals 0.75 and 0.50, columns (2) and (3). Qualitatively, the patterns of the baseline model remain. Quantitatively, the changes in TFPR are dampened because TFPR is now partly determined by wedges which we assume do not change with the counterfactual.

7.2. Other specifications

Skill intensity as differentiation. In Section 5, we separately identify less-differentiated from differentiated firms as latent types. Here, we use skill intensity as a proxy for differentiation following literature that links quality to skill intensity, e.g., Verhoogen (2008), Khandelwal (2010), Manova and Zhang (2012), and in line with the empirical results of Section 2.4 that associate tariff cuts with switches to skill intensive sectors. We only observe workers' education in the 2004 cross-section. Using these data, we split firms into the 20 percent most skill intensive and the remaining firms in each sector. We match the predictions of the model for differentiated firms to the moments from the 20 percent skill-intensive firms, and the predictions for the less-differentiated firms to the remaining firms.

The counterfactual results in Table 6 column (4) are qualitatively similar to Table 5: Differentiation, markups and welfare (not shown) increase with the measure of small firms close to differentiation. Quantitatively, the increase in TFPR in the counterfactual where small firms are close to the margin of differentiation is the same as in the data, 3.2 log points, illustrating the model's ability to generate large responses of TFPR to trade.

Less-differentiated imports. We re-estimate the model and repeat the counterfactuals restricting Foreign firms to produce only less-differentiated varieties. The interpretation is that the differentiated varieties have a non-tradable component as in the examples of Xiaomi cell phones and Chery Automobiles. With this modification, competition tightens in L nests more than in the baseline model, and so more firms differentiate in most counterfactual simulations, though the difference is not large. Pro-competitive effects decreasing markups in L nests are larger and so the final effect on TFPR does not increase despite the increase in differentiation.

Bertrand competition. We re-estimate the model and repeat the counterfactuals assuming that firms compete à la Bertrand. As others have found, the model with Bertrand competition predicts too little variation in markups among small and middle-sized firms and fits the data worse than with Cournot competition (Appendix Table A14).[35] But the counterfactual results in Table 6 have similar magnitudes to the baseline model with Cournot competition.

8. Conclusion

We study the effect of foreign competition on Chinese non-exporting firms following the Chinese accession to the WTO. Reductions in Chinese import tariffs are associated with increases within firms in revenue productivity and the introduction of new goods. While these findings accord to the experience of other developing countries, they are puzzling from the perspective of standard trade models where import competition decreases markups and the incentives to incur costly investments in innovation.

We propose a model where innovation leads to the creation of new market segments. Firms respond to reductions in trade costs by innovating to escape foreign competition. A quantitative exercise illustrates how the model predicts changes in markups and the

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[35] See for example Edmond et al. (2015), Eaton et al. (2013), and Gaubert and Itskhoki (2021).

introduction of new goods that are much closer to the data than a standard model with no innovation among import-competing, non-exporting firms. The new innovation mechanism increases the welfare gains from trade.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jinteco.2023.103835.

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