Escaping import competition and Spillovers Through Backward Linkages

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1 Introduction

There is a long and venerable literature that emphasizes the gains from opening up to trade. Much of those gains are consumer-side benefits from greater variety and lower prices. A more recent literature emphasizes the positive effect of global competition in weeding out the less efficient firms and expanding the market share of the most efficient competitors (Melitz (2003)).

Surprisingly, there is not much theory where gains from trade arise because reductions to trade barriers improve the performance of import-competing firms. Empirical studies are roughly in line with the marked absence of theory on this point. Evidence to date on the effect of unilateral tariff or quota reductions on firm productivity is mixed (see, Tybout (2003) for a comprehensive review). Yet policy makers and trade economists in general do believe that trade reforms improve the performance of domestic competitors. If forced to give a reason why, a number of economists might vaguely resort to "x-inefficiency" or "dynamic gains from trade."

This paper aims to, at least in part, narrow the gap between policy maker's perceptions and the academic literature. On the empirical side, we argue that because competition puts downward pressure on revenues, a standard regression of unilateral tariff reductions on firm productivity is likely to confound productivity gains with reductions in markup. This measurement issue may explain the mixed results in the empirical literature above. Our solution is to focus on backward linkages. Evidence suggests that firms' improvements

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in productivity are accompanied by improvements in input suppliers.[1] But because input suppliers are not directly subject to foreign competition, their markups are much less likely to decrease than the markup of import-competing firms. So, studying the effects of tariff reductions on the measured productivity of upstream firms allows us to isolate the effects of tariffs on productivity. A literature pioneered by Javorcik (2004) identifies backward linkages as the primary source of productivity spillovers from multinational firms. We bring these insights to the context of trade reform. We use firm level data from China spanning the years of its accession to the WTO in 2001 to document spillovers from backward linkages (below).

On the theory side, we propose a model where firms may invest to differentiate their variety—i.e., to decrease the elasticity of substitution between its variety and its competitors'. An increase in import competition squeezes the firm's profit margins and pushes the firm to "escape" competition through product differentiation. This result contrasts with standard theories of trade and innovation, where innovation increases the efficiency to produce the same good and competition always decreases the incentives for firms to innovate.[2] Arguably, investment in product differentiation here better reflects the reality that R&D spending and managerial time is allocated to the creation of new market niches, where the firm can enjoy greater monopoly power.[3]

Mechanically, the economy features heterogeneous firms and variable markups with nested CES preferences à la Atkeson and Burstein (2008). Each firm chooses between producing a variety in a non-differentiated nest where the elasticity of substitution between varieties is high, or paying a fixed cost to invent a new nest where it holds monopoly power and faces a low elasticity of substitution. In a cross-section, investment in product differentiation is a non-monotonic function of firm productivity. If the firm is very unproductive, its sales are too small to pay for the fixed cost. If the firm is very productive relative to its competitors, then it will hold near monopoly power in the non-differentiated nest. It does not invest in differentiation because its markup is high without it. This result is reminiscent of the U-shaped pattern of competition on innovation found in Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Aghion, Cai, Dewatripont, Du, Harrison and Legros (2015). These models, however, are not amenable to analysing data because they feature only one active firm per sector. Our use of CES preferences brings their results closer to data and to standard trade literature.

[1] For example, Amiti and Konings (2007), Gopinath, Neiman (2014) and Goldberg et al. (2015) all associate decreases in input tariffs in developing countries to increases in firm productivity.

[2] See Lileeva and Trefler (2010) and Bustos (2011).

[3] This point is evident in *Foreign Affairs* (2015) interviews with entrepreneurs in its "Special Entrepreneurship Issue."

In mapping the model to data, we assume that a reduction in a sector-specific tariff increases competition especially in the non-differentiated nest. The interpretation is that firms with differentiated varieties compete more directly with firms in other sectors since they have carved out their own market niche. Under this interpretation, tariff reductions increase investments in product differentiation—i.e., firms escape competition by differentiating their products. But because markups depend negatively on market shares as in Atkeson and Burstein (2008), they decrease with import competition. So, as claimed above, tariffs have an ambiguous effect on the measured productivity of import-competing firms: They increase with their investments in product differentiation, but they decrease with the drop in markups. While we are not the first researchers to make this point, our solution to this empirical dilemma is novel. If firms with more differentiated products use more differentiated inputs, upstream suppliers invest in product differentiation, but their market shares and markups do not decrease.

We apply these theoretical insights to the case of China. The years between 1998 and 2007 witnessed many policy shifts as China embarked on significant trade reform. Average tariffs on manufacturing in China fell from 43 percent in 1994 to 9.4 percent in 2004, following China's accession to the WTO in 2001. These significant changes in tariff policy combined with China's WTO entry provide us with the opportunity to directly measure the impact of domestic trade reforms on firm markups, product differentiation, and productivity outcomes. Since the reforms were guided by WTO mandates to create a more uniform tariff structure, tariff reductions were largest on goods with initially the highest tariff levels. This allows us to use initial tariffs as instruments for tariff changes. We also use tariff changes combined with input-output tables to separately measure the impact of trade reform on Chinese domestic input suppliers. We follow Olley-Pakes to construct measures of total factor productivity (TFP).

Our main empirical finding is a large and robust effect of tariff reductions on TFP of upstream firms. The effect of tariff reductions on the TFP of import-competing firms is generally positive, but the effect is not as robust and its magnitude is smaller—consistent with the measurement issues highlighted by the model. For corroborating evidence that firms are investing in product differentiation, we turn to patenting data. The advantage of using patent filings is that they are unaffected by markup changes. Using a newly matched dataset that links patent filings for all enterprises in China with the industrial survey, we show that final-goods producers did respond to falling tariffs by significantly increasing their patenting of new products. We also show that firms that moved to new products systematically moved into sectors requiring more skilled labor. This finding is consistent with investments in product differentiation, given that a recent literature shows that higher-quality firms are more skill intensive, and it is inconsistent with the classic Heckscher-Ohlin model where import competition in China should push it toward its unskill-intensive comparative advantage sectors.[4]

In section 2, we begin the paper by reporting reduced-form results showing productivity responses to falling tariffs for final-goods producers, input tariffs, and domestic input suppliers. The only significant gains to productivity (TFP) from tariff reforms in China occurred via backward linkages. In Section 3 we develop a theoretical model that describes the process of productivity growth for both final-goods producers and upstream suppliers.

In Section 5, we report empirical results for markups, product shifting, and patent filing. The results highlight the opposite effects of tariffs on markups and innovation: markups fell for final-goods producers but they increased their innovative activity as shown by patent filings and product switching. Section 6 concludes.

2 The Impact of Tariffs on TFP

This section reports changes in total factor productivity (TFP) within firms as a function of final-goods tariffs, input tariffs, and tariffs in the downstream sectors. We describe the data in section 2.1. The method to measure TFP is in section 2.2 and empirical results are in section 2.3.

2.1 Data

The data are an annual survey of industrial firms collected by the Chinese National Bureau of Statistics. The data set is firm-level based and comprises *all* state-owned enterprises (SOEs), regardless of size, and *all* non-state-owned firms (non-SOEs) with annual sales of more than 5 million Yuan. We use a ten-year unbalanced panel dataset, from 1998 to 2007. For more details on the dataset, which has been used extensively in a number of papers, the reader is referred to Du, Harrison, Jefferson (2012), Aghion et al (2015), and Brandt et al. (2017)

The original dataset has 2,226,104 firm-year observations and contains identifiers that can be used to track firms over time. It includes firms in manufacturing, mining, electricity, gas, and water sectors. We keep only firms in manufacturing, the tradable sector. The sample size is further reduced by deleting missing values, as well as observations with negative or zero values for output, number of employees, capital, and the inputs. Due to

[4]See Verhoogen (2008) and Fieler, Eslava and Xu (2016).

incompleteness of information on official output price indices, which are reported annually in the official publication, three sectors are dropped from the sample.

The dataset contains information on output, fixed assets, total workforce, total wages, intermediate input costs, foreign investment, Hong Kong-Taiwan-Macau investment, sales revenue, and export sales. We use the criterion of zero foreign ownership to distinguish domestic firms and foreign owned firms. That is, domestic firms are those with zero foreign capital in their total assets. About 77.5 percent of observations meet the criterion of domestic firms, and 22.5 percent are designated as foreign firms. In this paper, we restrict the sample to domestic (ie non-foreign) enterprises with zero or minority state ownership. The final sample has 991,440 observations.

Data on China's Input-Output table are classified into 71 sectors, while the firm-level survey has 4-digit level industry classifications. Hence, to construct final goods, input, and backward linkage tariff changes, we aggregate the 4-digit classifications up to these 71 sectors. For example, the furniture industry (coded as 19 in Table 2) includes 5 four-digit sub-sectors. These are wood furniture manufacturing (2110), bamboo furniture manufacturing (2120), metal furniture manufacturing (2130), plastic furniture manufacturing (2140), and other furniture manufacturing (2190).

Our measurements of tariffs, described below, have this same 71-sector level. This sector classification is sufficiently broad to diffuse potential concerns that tariffs depend endogeneously on the behavior of disaggregated firms. Nevertheless, we estimate the impact of tariffs on TFP using both an OLS and an IV approach. We report the results separately for firms that exclusively sell in the domestic market, as well as firms that export a non-zero share of their output. We expect results to be stronger for non-exporters because our mechanism is driven by import competition and our tariffs measure foreign firms' access to the Chinese market, not the Chinese export expansion.

2.2 Measuring TFP and Tariffs

TFP. We measure total factor productivity for each firm and year using a standard two-stage procedure developed by Olley, Pakes (1996). In the first stage we estimate a three-input gross-output production function. We use the estimated factor output elasticities for labor, capital, and materials to construct measures of total factor productivity (TFP) for each firm in each year it appears in our 1998-2007 sample. In the second stage, we regress the dependent variable, lnTFP, on our three tariff measures and an extensive set of controls.

The first-stage production function is:

$$\ln Y_{ijt} = \alpha_0 + \alpha_L \ln L_{ijt}\alpha_M + \alpha_M \ln M_{ijt} + \alpha_K \ln K_{ijt} + \mu_{ijt} \tag{1}$$

where α_0, α_L, α_K and α_M are parameters to be estimated, subscript i refers to an individual firm in sector j and in year t. Variable Y is deflated output, L is number of employees, K is capital, M is material inputs, defined in detail below. The purpose of the first-stage is to get unbiased estimates of the factor-output elasticities.

All output and input variables are deflated by their corresponding price indices. In order to create a constant price output series, we deflate the output value (quantities*prices) by the 29 individual sector ex-factory price indices of industrial products. Hence for the purpose of creating constant price measures of the inputs, the 29 sector price indices are assigned with as much consistency as possible to the output data for the 71 sector aggregates. Capital is defined as the net value of fixed assets, which is deflated by a uniform fixed assets investment index, and labor is a physical measure of the total number of employees. Intermediate inputs purchased by firms for the purpose of producing gross output are deflated by the intermediate input price index. It is important to note that these deflators do not fully capture changes in prices in an environment where varieties are differentiated within sectors and firms invest in new varieties. So, measured TFP still picks up markups.

In the second-stage, we regress firm-level TFP on a series of firm-level and sector-level controls:

$$\begin{aligned} \ln TFP_{ijt} =& \beta_1 + \beta_2 StateShare + \beta_3 Output\_Tariff_{jt} + \beta_4 Input\_Tariff_{jt} \\ &+ \beta_5 Backward\_Tariff_{jt} + S_{jt} + \Sigma\alpha_i + \Sigma\alpha_t + \varepsilon \end{aligned} \tag{2}$$

where $\ln TFP_{ijt}$ is set equal to the predicted value of $\ln Y_{ijt} - \hat{\alpha}_L \ln L_{ijt} - \hat{\alpha}_M \ln M_{ijt} - \hat{\alpha}_k \ln K_{ijt}$ from equation (1) above. In equation (2) α_i are establishment-level fixed effects, the S_{jt} are sector-level time-varying variables such as industrial policies and sectoral foreign investment and α_t are annual time dummies.

Tariffs. Our time series of tariffs is collected from the World Integrated Trading Solution (WITS), maintained by the World Bank. We created a concordance between the tariff data, China's Input-Output table and the Chinese survey data at the most disaggregated level possible given the fact that the two data sources are not in the same nomenclature. We end up with a total of 71 sectors. For example, we have different categories for ship-building, electronic computers, tobacco products, motor vehicles, and parts and accessories for motor vehicles. To aggregate the tariff line items to the level which would allow us concordance with the survey, we used output for 2003 as weights.

To construct input tariffs and backward tariffs, we use China's Input-Output table (2002) and follow the procedures suggested by Amiti and Konings (2007). The input tariffs are constructed as a weighted average of the output tariffs, where the weights are based on the Input-Output table. For instance, if a chocolate producer uses 60 percent sugar and 40 percent cocoa powder, the input tariff for that chocolate industry is equal to 60 percent of the sugar tariff plus 40 percent of the cocoa tariff. Since China's input-out tables only allow us to calculate input tariffs at the three-digit level, we use the same level of 3-digit disaggregation for backward and final-goods tariffs as well.

More specifically, the tariff on inputs is calculated as:

$$\text{input\_tariff}_{jt} = \sum_{m \neq j} \delta_{jm} \left[\frac{\sum_{i \in m} \text{output\_tariff}_{it}(Y_{it} - X_{it})}{\sum_{i \in m}(Y_{it} - X_{it})} \right]$$

where δ_{jm} is the share of sector m provided as an input to sector j, Y_{it} is the output of sector i in year t, and X_{it} is the exports of sector i in year t. The backward tariff is calculated as:

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

where α_{jk} is the share of sector j's production supplied to downstream sector k. The values of α_{jk} and δ_{jm} are both taken from the 2002 input-output table. Backward tariffs will be highest in those sectors j where the downstream users in sector k face high tariffs and demand a large share of sector j's output. This concept of a "backward tariff" is a new one and showing that tariff changes had a major impact via this channel is a primary contribution of this paper.

We also include a number of controls, such as exposure to foreign investment at the sector level, other policies, and ownership variables. Following Javorcik (2004), we define three sector-level FDI variables. First, Horizontal_{jt} captures the extent of foreign presence in sector j at time t and is defined as foreign equity participation averaged over all firms in the sector, weighted by each firm's share in sectoral output. Second, Backward_FDI_{jt} captures the foreign presence in the sectors that are supplied by sector j . Therefore, Backward_FDI_{jt} is a measure for foreign participation in the downstream industries of sector j. Forward_FDI_{jt} is defined as the weighted share of output in upstream industries of sector j produced by firms with foreign capital participation. The reader is referred to Javorcik (2004) for more details on the construction of the FDI variables. As indicated earlier, the degree of detail is quite high. While Amit and Konings (2007) use 4-digit measures of protection for Indonesia, we can only use 3-digit measures in order to be consistent across our FDI and tariff measures.

2.3 Results on Revenue TFP and Trade

Our baseline results are reported in Table 1. The sample includes all establishments without foreign ownership or significant public ownership (although the results are not qualitatively affected by the inclusion of this additional set of enterprises). The first two columns report the OLS results using either the OP approach or OLS with firm fixed effects in the first stage. All specifications allow for both firm fixed effects and year effects. While all results reported here use the log of tariffs as a measure of tariffs, the results are similar if we instead use actual tariffs or their lagged levels.

Our key results are in the last three rows of Table 1, which report coefficients on final-goods tariffs, the backward tariff, and input tariffs. For our OLS results in the first two columns of Table 1, only the coefficient on the backward tariff is significant. It is consistently negative, suggesting that a one percentage reduction in tariffs facing downstream firms would lead to an increase in TFP for upstream enterprises supplying those firms of .10 to .13 percent.

One possibility that we address is that tariffs are endogenous to individual firm performance. Like in other trade liberalizations, China reduced both the levels and the heterogeneity in tariffs. Tariff reductions between 1998 to 2007 were highest in those sectors where tariff levels were high at the beginning of the sample period, in 1998. Following the literature, we use initial tariffs as instruments.[5] Final goods tariffs, input tariffs, and backward tariffs are instrumented using the initial period value for these tariffs at the establishment level, a dummy variable equal to one after China entered into the WTO, and the interaction of the WTO dummy with the initial tariff levels. If the firm did not exist in 1998, we use instead the initial mean tariff in the firm's sector.

These instrumental variable (IV) estimates reported in columns (3) and (4) of table 1. The coefficient on the WTO dummy in the first stage is highly significant and negative, indicating that China's entry into the WTO led to significant tariff declines across all manufacturing sectors. For the IV estimates, the coefficient on final-goods tariffs in the OLS and OP specifications become significant but opposite in signs. The coefficient on backward tariffs remains significant and negative across all specifications, however, with

[5] This instrument is standard. For example, Goldberg and Pavcnik (2007) use it for India and Attanasio, Goldberg, Pavcnik (2004) use it for Colombia. A similar approach to instrumenting Chinese tariffs is followed by Brandt et al (2017). They instrument for tariffs using rates from the accession agreement, which were mostly fixed by 1999.

significant increases in magnitudes. The results in the first four columns of Table 1 indicate that the negative and significant impact of backward tariffs is robust across a variety of (OLS and IV) estimation approaches.

These results control for a number of potential confounding factors, including other types of industrial policies, the degree of competition in the sector, and the possibility of upstream and downstream linkages from foreign investment. Industrial policy is captured through zero-one dummy variables indicating whether the firm received subsidies (" index_subsidy"), whether the firm received a tax holiday ("index_tax"), and whether the firm paid below median interest rates on loans ("index_interest"). The results suggest that subsidies and tax holidays are associated with higher TFP at the firm level, while subsidized interest rates are associated with lower TFP. The impact of vertical linkages from foreign investment is generally positive and significant, while horizontal linkages are insignificant in the OLS specifications but positive and significant in the IV specifications.

Columns (5) through (8) repeat the estimation but exclude exporting enterprises. The results are similar to those reported in the first four columns. The only differences are in the magnitudes. The impact of backward tariffs increases significantly in both the OLS and IV estimates. When firms do not export, the positive impact of a reduction in tariffs for downstream users of a firm's products are even greater.

Loren Brandt, Johannes Van Biesebroeck, Luhang Wang, and Yifan Zhang, (2017), in their paper "WTO Accession and Performance of Chinese Manufacturing Firms", report quite different results for the impact of final-goods tariffs on TFP. While the main innovation of our paper is the focus on backward trade linkages, it is still important to reconcile our results on final-goods tariffs with theirs. After thoroughly investigating their approach, we find that the difference hinges on whether or not one drops observations for enterprises that changed sectors during the sample period. Brandt et al argue that it does not make sense to estimate the impact of tariff changes on firms that switch sectors. Consequently they either drop firms that switch sectors or control for them by including sector dummies in the estimation.

We retain all establishments but show how the two groups of firms responded differently to final-goods tariff changes in Table 2. The first four columns of Table 2 include only firms that remain within the same sector over the entire sample period. This is the group of firms in Brandt et al (2017). The remaining four columns include only firms that changed sector affiliation during the sample period. This is the group of firms dropped by Brandt et al (2017). The first four columns, show the significant and negative impact of final-goods tariffs on productivity as reported by Brandt et al (2017).[6] The effect is

[6]The coefficients are slightly different, due to the fact that we are using logs of tariffs instead of levels

significant and robust across both OLS and IV specifications. The last four columns of Table 2 include only firms that change sectoral affiliation. For these firms, the coefficient on final-goods tariffs switches sign—it is now positive and statistically significant.

In sum, Table 2 explains the apparent inconsistency between Brant et al. and Table 1 where all observations are combined. More importantly, the coefficient on our variable of interest, backward tariffs, is consistently negative across all specifications whether or not we allow for the endogeneity of trade policies, or sector switching. In the IV specification in both sets of firms, the coefficient on backward tariffs is at least twice as large as the coefficient on final-goods tariffs. Our argument throughout is that the coefficient on final-goods tariffs (but not backward tariffs) is upward biased because markups increase with tariffs. Tables 1 and 2 show that the most significant and robust impact of the unilateral tariff reductions in China between 1998 and 2007 on TFP was the impact on suppliers to sectors with falling protection. This effect has not been identified previously in the trade literature.

These results are fully consistent with the theoretical framework below: While both final-goods producers and their suppliers may be upgrading as a result of trade reforms, final goods producers are also like to experience significant downward pressure on markups. These markup reductions exert opposite effects on observed TFP, and if significantly large, they can lead to observed TFP declines. Consequently, unpacking the effects on markups is an important component of the story, and we proceed to do so both theoretically and empirically in the remainder of this paper.

3 The model

The objective of the model is to study final-goods producers' investment in product differentiation and markups. It highlights the opposing effects of these two decisions have on measured TFP when import competition tightens. We do not model explicitly the decision to patent or the firms' demand for skilled labor and differentiated material inputs. These decisions are modeled elsewhere.[7] In linking investments in product differentiation to increases in patenting, skill intensity, and the purchase of material inputs we rely on a large empirical literature suggesting the connection between these outcomes within the

to be consistent with the log of TFP as the dependent variable. Brandt et al get the same general result on final-goods tariffs either when they restrict the sample to firms that do not change sector identification or when they include sector dummies to control for the impact of changing sectors on TFP changes.

[7]Fieler, Eslava, Xu (2016)

firm.[8] Section 4 explicitly discusses the assumptions we make in interpreting data.

It's a small open economy. The empirical section exploits cross-sectoral differences in China and any single sector in China is unlikely to affect wages in the rest of the world. Heterogeneous firms have monopoly rights over their differentiated varieties. Time is discrete. Firms pay a sunk cost to enter and a fixed cost to produce in each period. This sunk cost implies that a decrease in import tariffs may temporarily increase the number of varieties and decrease the price index—as in Alessandria, Choi, Ruhl (2015). Preferences are a nested CES and firms charge variable markups as in Atkeson and Burstein (2008). In each period, a firm may pay a fixed cost to differentiate its variety. This investment amounts to the invention of a new nest in the CES aggregator, which decreases the elasticity of demand that the firm faces.

R&D is typically modeled as a productivity-enhancing investment, and product improvements are seen as isomorphic to productivity increases. In reality, R&D spending and managerial time is often allocated to the creation of new market niches, where the firm can enjoy greater monopoly power. Investment in product differentiation here captures this type of investment. Demand is in section 3.1, technologies in section 3.2, and the equilibrium is defined in section 3.3. Section 3.4 solves the firm's problem.

3.1 Preferences

Demand is nested CES. Total spending is inelastic and normalized to one. Spending on a variety i with price p is

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

where the elasticity of substitution $\sigma > \eta > 1$, n is the nest of variety i, P_n is the price index of the nest and P is the overall price index:

$$P_n = \left[\sum_{i' \in \Omega_n} p_{i'}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

$$P = \left[\sum_{n \in N} P_n^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

where Ω_n is the set of firms in nest n and N is the set of nests. There are two types of nests. Nest 0 contains all non-differentiated varieties. When a firm has a differentiated

[8] Researchers typically report separately the relation between inputs and productivity (e.g., Kugler, Verhoogen (2012), Goldberg, Khandelwal, Pavcnik, Topalova (2010)). For the correlation between a broader set of firm characteristics, see Bernard, Jensen, Redding, Schott (2007), Hottman, Redding, Weinstein (2016), Bloom, Manova, Van Reenen, Sun, Yu (2016).

variety, it is the single producer in its own nest. Then, $P_n = p_i$ and demand reduces to $x = (p/P)^{1-\eta}$.

3.2 Technologies

Each firm has monopoly rights over a unique variety. We denote the firm and its variety with i. In each period, there is a fixed production cost f_P and the firm may pay an additional cost f_D to differentiate its product. As described above, firms with differentiated products are the single producers within a CES nest. Firms are heterogeneous in their productivity. Firm i's marginal cost is $1/\phi_i$, irrespective of whether the firm invests or not in product differentiation.[9] As in Melitz (2003) productivity parameter ϕ_i is to be interpreted as productivity adjusted for quality. Thus the model, like Melitz, has no predictions for prices only for markups.

3.3 Equilibrium

Time is discrete and infinite. In the beginning of each period t, there is a finite number of firms N_{t-1} from the previous period. Each period has the following successive stages:

- **Stage 1.** Firms surviving from period $t-1$ exit with probability δ.
- **Stage 2.** A large mass of entrepreneurs decides to enter or not. To enter, they pay a fixed entry cost f_E. Entrepreneurs enter sequentially so that all entering entrepreneurs have expected profits greater than or equal to f_E. Firms surviving from stage 1 do not pay this cost.
- **Stage 3.** All firms, new and old, draw a productivity ϕ from a common distribution. All firms' productivity is common knowledge.
- **Stage 4.** In order of productivity ϕ, firms make decisions to produce or not, and to differentiate their products or not. If the firm decides to produce, it pays a fixed cost f_P. If it invests in product differentiation, it pays an additional cost f_D.
- **Stage 5.** Firms simultaneously set prices. A set of foreign firms set prices p_i^*. The set of foreign firms and their prices p_i^* are exogenous and known since the beginning of the period.
- **Stage 6.** Profits are realized. All firms survive to stage 1 of period $t+1$.

[9] It is simple to allow the investment to change productivity, but such a change does not add any insights. Clearly, firms are more likely to invest if the investment decreases their marginal cost.

An equilibrium is a set of strategies by firms, in each period and each stage, where all firms maximize profits given its information set at the time and other firms' strategies.

The rationale for the dynamics is as follows. First, in a static model with free entry, import competition generally has no effect since the exogenous entry of foreign firms is offset by exit of domestic firms. Profits and the price index generally remain unchanged. With dynamics and sunk cost f_E, a sufficiently large exogenous increase in the set of foreign firms or decrease in foreign prices induces a temporary overshooting of varieties as in Alessandria, Choi and Ruhl (2015). Price indices P and P_0 may temporarily fall pushing expected profits below f_E so that no firm enters in stage 2.

Second, for simplicity and as in Melitz (2003), all firms decisions are static because firms do not inherit productivity from previous periods. Third, the sequential decisions of stage 4 are an equilibrium selection. For any set of discrete choices in stage 4, stage 5 delivers a unique equilibrium. With perfect foresight, more productive firms maximize their profits over all possible scenarios of stage 5 given its discrete choices and other firms' best responses. In stage 2, profits decrease monotonically to zero if the number of firms go to infinity. So, the optimal number of entering firms is also unique. By backward induction, since uniqueness holds in all stages, it holds in the game as a whole. More specifically, if for a given set of parameters a firm is indifferent between discrete decisions in stages 3 or 4, a small perturbation of parameters breaks the indifference.

3.4 Firm's problem

Pricing. We study the problem of an individual firm and suppress its subscript i. A firm with productivity ϕ in nest n chooses price to maximize operating profit:

$$\max_p Y P^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma}(p - 1/\phi)$$

The first order conditions imply

$$\left[(\sigma-\eta)\frac{p}{P_n}\frac{dP_n}{dp_n} + (\eta-1)\frac{p_n}{P}\frac{dP}{dp}\right](p-c) + \sigma c = (\sigma-1)p \tag{4}$$

where the price elasticities are:

$$\frac{p}{P_n}\frac{dP_n}{dp} = \left(\frac{p}{P_n}\right)^{1-\sigma} \equiv s_n \tag{5}$$

$$\frac{p}{P}\frac{dP}{dp} = P^{\eta} P_n^{\sigma-\eta} p^{1-\sigma} \equiv s \tag{6}$$

In words, s_n is the firm's market share in the nest, and s is the overall market share. Substituting these elasticities into equation (4), the optimal markup over marginal cost is $\frac{\epsilon}{\epsilon-1}$ where ϵ is the endogenous elasticity of demand with respect to price:

$$\epsilon = \sigma(1 - s_n) + \eta(s_n - s). \tag{7}$$

The elasticity is a weighted average between the elasticity σ within the nest, η the elasticity across nests, and the Cobb-Douglas elasticity 0 because total spending is inelastic.[10]

Equations (5), (6) and (7) implicitly define the elasticity ϵ as a function of the firm's productivity ϕ and its decision to invest in product differentiation. If it does not invest, $P_n = P_0$, and we denote its elasticity ϵ_0. If it invests, $P_n = p$, $s_n = 1$ and its elasticity reduces to

$$\epsilon_D = \eta(1 - s).$$

Its operating profit without and with product differentiation is, respectively

$$\pi_0(\phi) = YP^{\eta-1}\frac{P_0^{\sigma-\eta}}{\epsilon_0}\left(\frac{\epsilon_0}{(\epsilon_0 - 1)\phi}\right)^{1-\sigma},$$

$$\pi_D(\phi) = \frac{YP^{\eta-1}}{\epsilon_D}\left(\frac{\epsilon_D}{(\epsilon_D - 1)\phi}\right)^{1-\eta}.$$

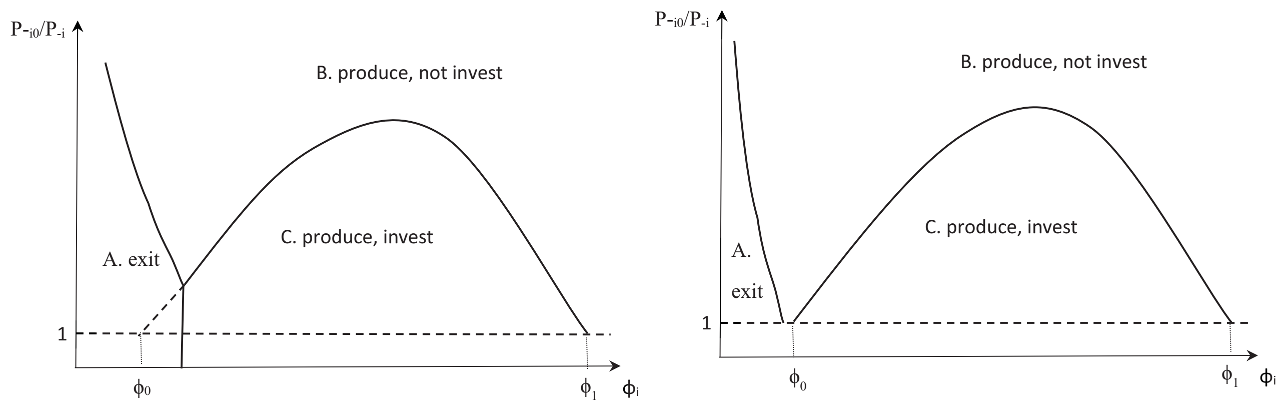
It is straightforward to show that net of fixed costs, investment in product differentiations is always profitable $\pi_D(\phi) \geq \pi_0(\phi)$ for any ϕ.[11]

Exit and investment. The firm's discrete choices are:

- exit if $f_P > \max\{\pi_0(\phi), \pi_D(\phi)\}$
- else produce a non-differentiated product if $f_D > \pi_D(\phi) - \pi_0(\phi)$
- otherwise produce a differentiated product

[10]This assumption of inelastic spending can easily be relaxed by assuming an upper nest with a continuum of sectors. Atkeson and Burstein (2008) is the special case where the number of differentiated products is sufficiently large (continuum) so that $s = 0$ for all firms.

[11]See appendix A.1.



(a) High f_p (b) Low f_p

Figure 1: Examples of discrete choices for a given P_{-i}

The contribution of other firms to price indices P and P_0 is respectively

$$P_{-i} = \left[\sum_{n \in N} \left(\sum_{i' \neq i, i' \in \Omega_n} p_{i'}^{1-\sigma} \right)^{\frac{1-\eta}{1-\sigma}} \right]^{\frac{1}{1-\eta}},$$

$$P_{-i0} = \left(\sum_{i' \neq i, i' \in \Omega_0} p_{i'}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$$

In equilibrium, the firm takes P_{-i} and P_{-i0} as exogenous. In analyzing the firm's problem, the ratio $\frac{P_{-i0}}{P_{-i}}$ is useful because it captures the contribution of non-differentiated varieties to the overall price index. When $\frac{P_{-i0}}{P_{-i}} = 1$ then all other firms are non-differentiated, and $\frac{P_{-i0}}{P_{-i}} = \infty$ all other firms are differentiated. For any given $P_{-i} < \infty$, figure 1 summarizes the effect of productivity ϕ and $\frac{P_{-i0}}{P_{-i}}$ on the firms's discrete choices.[12] Each graph is divided into three regions: Firms in region A exit; firms in region B produce and do not invest in product differentiation; firms in region C produce and invest in differentiation.

We start with the exit schedule. The fixed cost of production is positive and operating profits π_0 and π_D are both increasing in ϕ and tend to zero as ϕ tends to zero. Then, for any pair, P_{-i}, P_{-i0}, there is a sufficiently low productivity cut off so that all firms with productivity lower than the cutoff exit. The schedule separating regions A and B is downward sloping because profit $\pi_0(\phi)$ is increasing in the ratio $\frac{P_{-i0}}{P_{-i}}$ for any given P_{-i} (see

[12]We assume $P_{-i} < \infty$ because, with inelastic total spending, the monopolist's problem does not have a solution. Its profit tends to 1 (total spending) as its markup tends to infinity and quantity tends to zero.

appendix A.2). The schedule separating regions A and C is vertical because π_D depends only on the overall price index P_{-i} not on the ratio $\frac{P_{-i0}}{P_{-i}}$. Panels (a) and (b) represent two cases. Fixed cost of production f_P shifts the exit schedule to the right, and does not change the bell-shaped investment schedule. Hence, for sufficiently low f_P the two schedules will not cross, as shown in panel (b).

Assume that the fixed cost of product differentiation f_D is sufficiently low so that at least some firms invest. We prove the shape of the schedule separating regions B and C in various claims.

Claim 1. When $\frac{P_{-i0}}{P_{-i}} = 1$, there exists a productivity ϕ_0 such that firms do not invest if $\phi < \phi_0$.

Proof. As $\phi \to 0$, the profit from innovation tends to zero. This result holds for any $\frac{P_{-i0}}{P_{-i}}$ but to prove the overall claim, we only need $\frac{P_{-i0}}{P_{-i}} = 1$.

$$\begin{aligned}
\lim_{\phi \to 0} [\pi_D(\phi) - \pi_0(\phi)] &\geq \lim_{\phi \to 0} \pi_D(\phi) \\
&= \lim_{\phi \to 0} \frac{YP^{\eta-1}}{\epsilon_D} \left(\frac{\epsilon_D}{(\epsilon_D - 1)\phi} \right)^{1-\eta} \\
&= \lim_{\phi \to 0} \frac{YP_{-i}^{\eta-1}}{\eta} \left(\frac{\eta}{(\eta - 1)} \right)^{1-\eta} \phi^{\eta-1} \\
&= 0.
\end{aligned}$$

where the third line uses the limit $\lim_{\phi \to 0} \epsilon_D = \eta$. ■

Claim 2. When $\frac{P_{-i0}}{P_{-i}} = 1$, there exists a productivity ϕ_1 such that firms do not invest if $\phi > \phi_1$.

Proof. We show that, as ϕ tends to infinity, both π_D and π_0 tend to 1. Hence, the profit from investing in product differentiation, $\pi_D - \pi_0$ goes to zero. The claim again holds for any $\frac{P_{-i0}}{P_{-i}}$ but to prove the overall claim, we only need $\frac{P_{-i0}}{P_{-i}} = 1$.

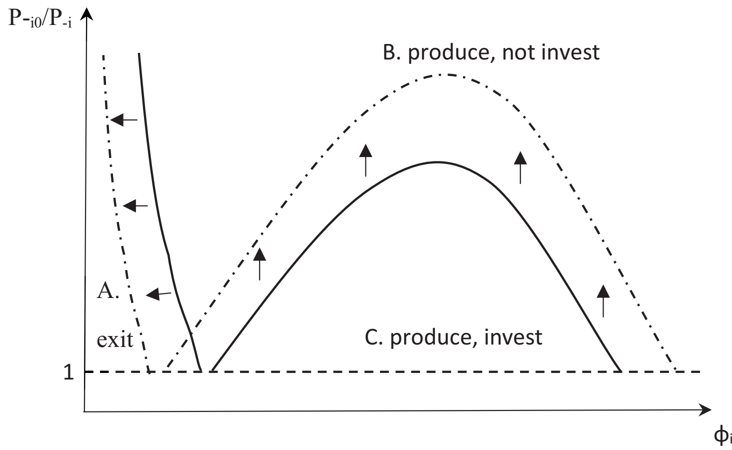
$$\lim_{\phi \to \infty} \pi_D = \lim_{\phi \to \infty} \frac{p^{-\eta}}{P_{-i}^{1-\eta} + p^{1-\eta}} (p - c) = \lim_{\phi \to \infty} \frac{p^{1-\eta}}{P_{-i}^{1-\eta} + p^{1-\eta}} = 1$$

As $\phi \to \infty$, the firm's market share tends to one and its markup tends to infinity. Then $(p - c) \to 1$ and $\frac{p^{1-\eta}}{P_{-i}^{1-\eta} + p^{1-\eta}} = 1$. The proof for π_0 holds identically except that η is substituted for by σ. Intuitively, a very productive firm does not find it profitable to invest in product differentiation because it is able to charge high markups even if its product is non-differentiated. ■

Claim 3. Profit from investing decreases in $\frac{P_{-i0}}{P_{-i}}$.

Although the formal proof of claim 3 is in appendix A.2, the result simply states that

Figure 2: Effect of an increase in P_{-i} on the firm's discrete choices



as the non-differentiated nest 0 becomes less competitive, profits from investing decrease. These claims together imply that, as drawn in figure 1, the set of firms investing is bounded and expands as P_{-i0}/P_{-i} decreases.[13] Figure 2 illustrates the effect of an increase in the overall price index P_{-i} on the firm's discrete choice. Appendix A.3 shows that P_{-i} shifts the exist schedule to the left because it increases operating profits π_D and π_0, and P_{-i} increases the difference $(\pi_D - \pi_0)$ so that the set of investing firms expands.

To summarize, firms charge variable markups. *Ceteris paribus*, firms with differentiated products have higher markups. These firms are not necessarily the most productive. The model captures the notion that firms with near monopolies in their sectors do not invest in product differentiation—they charge high markups for inferior products. An increase in competition through a decrease in P_{-i0}/P_{-i} increases exit of the least productive firms with non-differentiated products, and it unambiguously increases investment in product differentiation by survivors. In particular, it may spur old monopolists to improve their products. An increase in overall competition through a decrease in P_{-i} also increases exit but it decreases investment in differentiation among survivors.

These results contrast with predictions of trade models where R&D investment only increases productivity—e.g., Bustos (2011), Lileeva and Trefler (2010). Investment in these models depends only on economies of scale. So, more productive firms and monopolists are more likely to invest, and import competition always decreases investment in R&D. Our results are closer to Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and

[13]The figure also depicts this set as convex. We have not proved convexity, though none of our results depend on it.

Aghion and Griffith (2008). Like in these models, competition has a non-monotonic effect on investment in R&D. When market competition is too lax and existing firms hold near monopolies, they do not invest. When competition is too tight, firms do not invest in R&D because operating profits are too small to compensate for the fixed investment. The key advantage of our model is that these papers are difficult to map to data because in all equilibria there is only one active firm per sector. All other firms affect the equilibrium only through their threat of entry, but they are never observed.

3.5 Small firms

The model significantly simplifies if the number of firms is sufficiently large, and firms do not internalize the effect of their price on price indices P, P_0. Then, markups are $\epsilon_D = \frac{\eta}{\eta-1}$ under differentiation, and $\epsilon_0 = \frac{\sigma}{\sigma-1}$ under non-differentiation. Operating profits are:

$$\pi_0 = \frac{1}{\sigma}\left(\frac{\sigma}{(\sigma-1)\phi}\right)^{1-\sigma} P_0^{\sigma-\eta} P^{\eta-1} \tag{8}$$

$$\pi_D = \frac{1}{\eta}\left(\frac{\eta}{(\eta-1)\phi}\right)^{1-\eta} P^{\eta-1} \tag{9}$$

where $\pi_0 < \pi_D$ for any P and P_0. Analogous to the case of large firms, we study the effect of ϕ, P and P_{-i} on firm's discrete choices. The shape of the exit schedule does not change. It is evident from equations (8) and (9) that both π_0 and π_D go to zero as ϕ tends to zero. So, sufficiently unproductive firms exit. Also as before, π_0 increases in P_0 and π_D does not depend on P_0 for a given P. Hence, productivity cutoff for exit decreases in P_0 in the non-investment region B and it is constant in the investment region C.

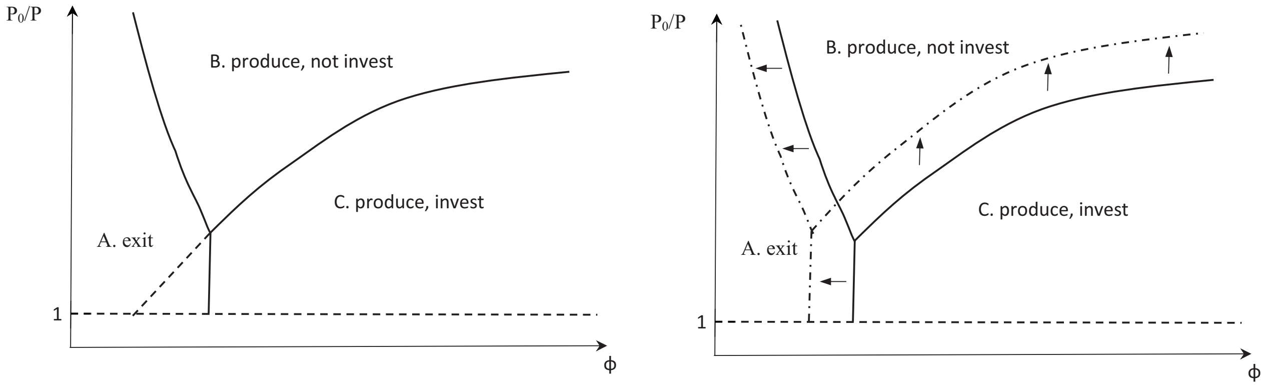
The firm invests in product differentiation if

$$\begin{aligned} f_D &\leq \pi_D - \pi_0 \\ &= P^{\eta-1}\left[\frac{1}{\eta}\left(\frac{\eta}{(\eta-1)\phi}\right)^{1-\eta} - \frac{1}{\sigma}\left(\frac{\sigma}{(\sigma-1)\phi}\right)^{1-\sigma} P_0^{\sigma-\eta}\right] \end{aligned}$$

The last expression is clearly increasing in the overall price index P and decreasing in P_0.

Claim 4. For all P, P_0, there exists a single cutoff ϕ_D such that conditional on entry, firms invest if and only if $\phi \geq \phi_D$.

Proof. It suffices to prove that $\frac{d(\pi_D - \pi_0)}{d\phi} > 0$. By the envelope theorem, the derivatives



(a) For a given P (b) An increase in P

Figure 3: Discrete choices when firms are small

of operating profits with respect to firm productivity ϕ is

$$\frac{d\pi_D}{d\phi} = \frac{\partial \pi_D}{\partial \phi} = (1-\eta)\frac{\pi_D}{\phi}$$
$$\frac{d\pi_0}{d\phi} = \frac{\partial \pi_0}{\partial \phi} = (1-\sigma)\frac{\pi_0}{\phi}$$

We want to show

$$\frac{d(\pi_D - \Pi_0)}{d\phi} = (1-\eta)\frac{\pi_D}{\phi} - (1-\sigma)\frac{\pi_0}{\phi} > 0 \quad \Leftrightarrow \quad \frac{(\eta-1)\pi_D}{(\sigma-1)\pi_0} < 1$$
$$\frac{(\eta-1)\pi_D}{(\sigma-1)\pi_0} = \left(\frac{\eta-1}{\sigma-1}\right)\frac{\sigma}{\eta}\left(\frac{\eta}{\eta-1}\right)^{1-\eta}\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1}\left(\frac{P_0}{\phi}\right)^{\sigma-\eta}$$
$$= \left(\frac{\sigma}{\sigma-1}\frac{\eta-1}{\eta}\right)^{\eta}\left(\frac{\sigma P_0}{(\sigma-1)\phi}\right)^{\sigma-\eta} < 1$$

The first term is smaller than one because the exponent $\eta > 0$, and markups $\frac{\sigma}{\sigma-1} < \frac{\eta}{\eta-1}$. The second term is smaller than one because the price index is always smaller than the price of any individual firm $P_0 < p = \frac{\sigma}{(\sigma-1)\phi}$. ■

Discrete choices when firms are small are in figure 3. Figure 3(a) is an example for a given P, and 3(b) shows the effect of an increase in P on firm choices. With respect to figures 1 and 2, the key difference is that we loose the monopolists result. That is, if firms are sufficiently small to take price indices as given than investment always increases in ϕ. This monotonicity also holds in models where investment yields a productivity gain—e.g., Bustos (2011) and Lileeva and Trefler (2010). But different from these models, investment increases with import competition in the form of a decrease in P_0. The model can then reconcile decreases in sales with increases in investment.

4 Mapping the model to data

Section 4.1 presents and discusses assumptions used to map the model to data. Section 4.2 presents the predictions of the model.

4.1 Assumptions to interpret data

We make the following assumptions in mapping the model to data.

A1. Measured productivity captures markups.

A2. Patents Firms file patents when investing in product differentiation.

A3. Skills The production of differentiated products is more skill intensive than the production of non-differentiated products within sectors.

A4. Inputs (i) Differentiated goods are made with inputs of higher measured productivity. (ii) Within both set of goods—i.e., differentiated and non-differentiated—equilibrium in the downstream market does not change the unit cost of inputs or the measured productivity of upstream firms.

A5. Tariffs A decrease in output tariffs decreases P_{-i0}. Tariffs may also decrease P_{-i} but the dominating force is P_{-i0}.

Assumptions A1-A3 and A4(i) are easy to justify. (A1) is well known: Measures of productivity capture markups. When firms differentiate their products, they file more patents (A2) either because creating exclusive products requires more innovation or because firms have greater incentives to protect the monopoly power over their innovation. Assumptions A3 and A4(i) are backed by the literature on quality. There is ample evidence that firms of higher sales, quality and skill intensity sell buy and sell inputs at higher unit prices, suggesting the firms of higher quality hire more skilled workers and buy inputs of higher quality.[14]

[14] Quality is typically measured as the residual of a regression of sales on prices (see Khandelwal (2010)). For patterns of input purchases and skill intensity, see Verhoogen (2008), Eslava, Fieler and Xu (2015), Kugler and Verhoogen (2012), Voigtlander (2014). These papers do not directly measure

We assume A4(ii) for simplicity but also show in the empirical work that follows that it is supported by our data for China. Mechanically, we can rationalize it by assuming perfect competition in the input market. Input providers may still have positive markups, but if the number of firms is sufficiently large, then they all sell their product at the point of minimum average cost.[15] Without A4(ii), the link between equilibrium in the upstream and downstream markets may be complicated by strategic interactions when firms are large, as we assume here. Still, main forces are likely to reinforce our results. First, with monopolistic competition, when downstream firms upgrade, the mass of upstream firms producing differentiated inputs may increase thereby decreasing the relative costs of differentiated inputs. This effect would push downstream firms to upgrade further.[16] Second, import competition directly decreases the markup of downstream firms because it decreases these firms' market share, but since it does not change market shares of upstream firms, it need not change their markups.

Finally, we find support for this assumption in our data. It is consistent with anecdotal evidence indicating fierce domestic competition among suppliers in many sectors in China. As an illustration, Figure 4 shows that Apple's margins have been much greater than its major supplier Foxconn, which in turn had significantly greater margins than its supplier Pegatron. Consistent with both our modeling assumptions and anecdotal evidence for China, we show in the paper that China's trade reforms significantly reduced the margins of final goods producers but had no significant impact on the margins of their suppliers.

Assumption A5 sharpens the predictions of the model on the effects of tariffs. Price indices P_{-i} and P_{-i0} have opposing effects on firms' investment. Investment in product differentiation increases in P_{-i} and decreases in P_{-i0}. Our justification for A5 is that differentiated firms compete more directly with firms in other sectors. Then, a decrease in output tariffs in a sector directly decreases P_{-i0} through import competition, but their effect on P_{-i} is only indirect because P_{-i} may include (domestic and foreign) firms in other sectors.

4.2 Predictions of model

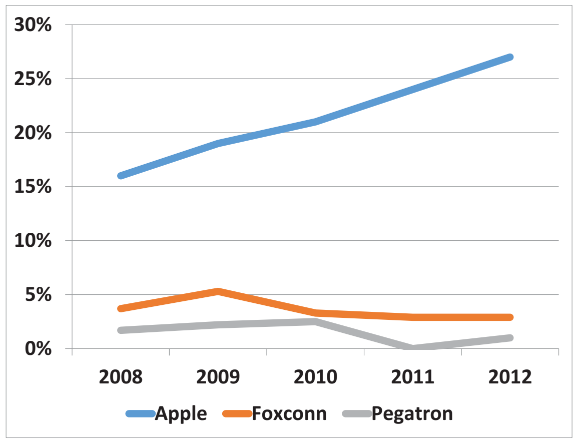
Cross-section. Assumptions A1, A3 and A4(i) together imply a positive correlation between a firm's measured productivity, skill intensity, and unit prices of output and material inputs. These correlations are well documented in the literature, as mentioned

firms' productivity, but measured productivity is generally correlated with these other firm performance measures—e.g., Hottman, Redding, Weinstein (2015) and Bloom, Manova, Van Reenen, Sun, Yu (2016).

[15] This is textbook justification for perfectly competitive markets—e.g., Varian (2010, chapter 22).

[16] This type of interconnection in investment in quality upgrading appears in Fieler, Eslava and Xu (2016). See Kee and Tang (2015) for the development of the input market in China.

Figure 4: Accounting Margins For Final Goods and Suppliers: Apple and its Suppliers as an Example



Sources: Adapted from Hon Hai Precision Industry Co. Ltd. Annual Report 2012 (2013); Apple Inc. Form 10K 2012 (2013); Pegatron 2012 Annual Report.

above, and our data are not particularly good to test them—we observe very little about firm's material purchases and skill intensity. Still, we do observe patent applications. Assumptions A1 and A2 imply that, within sectors, firms with higher measured productivity have more patents—even after controlling for total revenue or total value added to account for potential economies of scale in the filing of patent applications.

We cannot test predictions of the model across sectors because sectors may differ in many aspects that are not modelled. Still, we find the non-monotonic relation between ϕ on investment in product differentiation in figure 1 appealing. As previously mentioned, it implies that firms that are near monopolies charge high markups for inferior, non-differentiated products. Import competition may change these firms' behavior. Anecdotal evidence and case studies support this prediction.[17]

Tariffs. By assumption A5 and claim 3, tariff cuts unambiguously increase the incentives for surviving firms to invest in product differentiation. But tariffs have a negative effect on markups of firms that do not invest. In figures 1 and 3, a decrease in P_{-i0} unambiguously increases investment in product differentiation, but at the same time decreases markups of firms that do not change their investment status. Even for firms that do change their status, because P_{-i} may also decrease, the effect of tariffs on their markups is ambiguous.

[17]See Das, Krishna, Somanathan, Lychagin (2013) Holmes, Schmitz (2001), Schmitz (2005). See also Aghion, Bloom, Blundell, Griffith, Howitt (2005) for the non-monotonic relation between tightness of competition and investment in R&D.

In accordance with the data, the coefficient on output tariffs in Table 1, showing the link between final goods Revenue TFP and output tariffs, is not robust.

Assumptions A2-A4 are important because they point to other evidence that import competition increases product differentiation. A decrease in output tariffs increases (i) the measured productivity of input suppliers, (ii) patent applications and (iii) firm's skill intensity. These predictions are borne out in Tables 1 and 2 above and the tables in the remainder of this paper.

The effect of a decrease in P_{-i0} is heterogeneous across firms in figures 1 and 3, but it is difficult to directly test this heterogeneity without the location of the productivity cutoffs. This is especially true for the general case where some firms may be large, figure 1, since there are two cuttoffs—some of the smallest and largest firms may invest. In the literature, evidence for this heterogeneity is mixed.[18]

5 Empirical Results on Markups and Innovation

In the empirical section 2, the effect of tariffs on the TFP of import-competing firms is ambiguous—it is typically small and negative, but it is not robust. At the same time, tariffs have a large negative effect on the TFP of suppliers of these import-competing firms. In the model, tariff reductions lead both import-competing firms and their suppliers to differentiate their products and increase measured productivity. The effect of this investment in product differentiation, however, is confounded with decreases in the markups of import-competing firms. Section 5.1 uses accounting margins and sales reported in our data to check if profit margins and sales disproportionately fall for import-competing firms. Sections 5.2 and 5.3 search for evidence associating tariffs to investment in product differentiation using data on skill intensity and patents. We do not observe the skill intensity of per firm and year. But using data from 2004, the only year where firms' skill intensities are available, we construct measures of sectoral skill intensities. Section 5.2 shows that firms that switch sectors in response to tariff cuts generally switch to more skill-intensive sectors. Section 5.3 associates tariff cuts with increases in patenting.

To summarize, the results on skill intensity and patenting are very strong for firms that are directly impacted by import competition. Results are a lot weaker or non-existent for suppliers of these firms. In the model, both import competing firms and their suppliers invest in product differentiation. But these suppliers experience a spillover from

[18] More productive firms fare better in trade liberalization in Verhoogen (2008), Bustos (2011) and Fieler, Eslava and Xu (2016). In models of x-inefficiency, low-productivity firms improve performance to avoid exit when market tightens.

downstream firms. The effect of final-goods tariffs may be watered down to the extent that these firms supply inputs to other sectors or final goods.

5.1 Markups and Sales

We estimate the determinants of accounting profits, which we define as the establishment level reported gross profits in Chinese currency as a share of establishment revenues.[19] The survey form indicates that gross profits are defined as revenues less cost of goods sold. Our results are reported in Table 3. The first two columns report the results for all enterprises, while the next four columns separate the results into non-exporters (columns (3) and (4)) and exporters (columns (5) and (6)). Since the model was developed for firms targeting the domestic market, we expect the results to apply most strongly to the sample of enterprises that primarily sell domestically.

The results in Table 3 confirm the predictions of our model. Only final-goods tariffs positively and significantly affect accounting profits. Consistent with our assumption of perfect competition in the supplier sectors, backward tariffs generally have no significant impact on supplier firms. As expected these results are strongest and only significant for non-exporters. These markup results are consistent with results in Tables 1 and 2 indicating that positive TFP effects of tariffs in the final-goods sector are likely to be observationally difficult to identify due to declining revenue from falling markups.

The coefficient on log final-goods tariffs ranges from 0.36 to 0.79. For firms that do not export, this implies that a movement from tariffs of 100 percentage points to zero would lead to a reduction in ROS of between 0.7 to 1.5 percentage points. Since the average ROS in the sample is five percentage points and tariff cuts average 30 percentage points, this is a significant but not implausibly large effect.

An additional test of the model's assumptions is to look directly at the relationship between output and tariff changes. We expect a reduction in final-goods tariffs to directly decrease the sales of import-competing firms, but to have a smaller impact on their suppliers' sales.

Table 4 confirms this prediction. Final-goods tariffs are significantly and positively associated with firm level output, particularly for firms oriented towards the domestic market (with zero exports). Backward tariff reductions, however, either had an insignificant impact on output levels or were associated with increases. As expected, input tariff reductions had the biggest effects on output, leading to significant increases in output.

[19] An alternative is to follow De Loecker and Warzynski (2012). The issue with their measure is that it requires goods to be homogeneous within sectors, like Olley-Pakes. Loecker and Warzynski explicit admit that their results on measured productivity could be driven by quality upgrading (see page 2441).

5.2 Moving to higher quality goods

The theoretical framework suggests that firms will invest in upgrading in order to escape greater import competition caused by falling tariffs. We examine whether the China data are consistent with this hypothesis by looking at whether firms move to sectors requiring more skilled labor as tariffs decline. Since we do not directly observe quality, we proxy for the average quality of firms in a sector by using a one time survey conducted in 2004 by the survey that asked firms details on the composition of their labor force. We consequently measure quality as the share of a firm's labor force that is highly trained, defined as:

$$\text{Quality} = \frac{\text{skilled workers}}{\text{total workforce}}$$

where skilled workers include completed a three- or four-year college degree, senior high, mid- and high-level technicians, and mid- and high-level engineers. We could have chosen to use only a subset of these designations to define sectors as highly skilled intensive, but since all alternative measures are highly correlated with each other, the choice of which occupations to include is not critical. Once we identified this ratio, we then aggregated the firm level information to the sector level. This allowed us to rank sectors from highest quality to lowest quality, based on the number of highly skilled employees as a share of their workforce. This 2004 sectoral ranking was then used to classify sectors from highest quality to lowest quality, with the number of sectors around 450. In our data, the least skill intensive sector was the production of packaging and bags, while the sector with the highest ranking was a subsector of aircraft manufacturing.

We then merged the information on sectoral rankings with our panel of firms between 1998 and 2007. Table 5 shows the results of regressing sectoral rank (with highest indicating most skill-intensive, our proxy for high quality goods) at the firm level on a number of determinants. The first row of Table 5, which reports the impact of receiving a subsidy on sectoral rank, indicates that a firm receiving subsidies would move up on average by half a sector towards a higher quality ranked sector. Since all specifications include firm fixed effects, the identification stems from changes in sectoral affiliation within the firm.

Many of the coefficients reported in Table 5, while not the focus of this paper, are of interest in themselves and seem plausible. For example, the large and negative coefficient on sectoral export share indicates that a sector which moved from no exports to a 100 percent exports would move down the sectoral ranking by almost 200 steps. The results also suggest that additional foreign investment in the same sector is associated with an improvement in the ranking, while an increase in foreign investment downstream is associated with a large increase in the quality of suppliers (backward linkages).

For this paper, the coefficients of interest are the tariff variables. The first column reports coefficients using OLS, while the second column reports the IV specification. The middle two columns report OLS and IV results for non-exporters, while the last two columns report the same specifications for establishments with positive export sales.

The coefficient on the log of tariffs is consistently negative and significant, with point estimates ranging from -14 to -55. The results indicate that a decline in final-goods tariffs is associated with an increase in movement to more skill intensive sectors, as proxied by the sophistication and education of the labor force. The point estimates indicate that a one standard deviation reduction in log tariffs (around .5) would be associated with a movement up the rank of between 7 and 25 sectors. The coefficient on input tariffs is also negative, but smaller in magnitude, indicating that a reduction in tariffs on inputs would be associated with a movement up the rank towards higher skill-intensity. These results are consistent with both our theoretical framework as well as with the extensive literature on the gains from reducing tariffs on imported inputs, as illustrated by Amiti and others.

The coefficient on backward tariffs, however, is positive and significant, indicating that a tariff reduction in the downstream sector would be accompanied by a reduction in the skill intensity of local suppliers. Unlike the results for final-goods tariffs, the evidence suggests that a reduction in backward tariffs is accompanied by a movement down the skill-intensity ranking.

5.3 Measuring Quality Changes Using Patent Filings

An alternative measure of quality changes would be to use patent filings, which are collected by SIPO. Researchers He, Tong, Zhang and He (2016) have recently made available the results of a project to merge all patent filings in China at the establishment level with the industrial survey. Matching at the establishment level was accomplished through a number of algorithms which match exactly on establishment name for the period 1998 through 2009. The researchers have taken advantage of access to the State Intellectual Property Office (SIPO) and manually checked many of the actual merges that they performed.

Patent filings are divided into three types of patents: invention patents, utility patents, and design patents. According to Fang, He, and Li (2016), the distinction is as follows for Chinese patent filings:

> "China's State Intellectual Property Office (SIPO) grants three types of patents: invention patents, utility model patents, and design patents. Broadly speak-

> ing, an invention patent protects technical solutions or improvements relating to products or processes, while the utility model patent covers mostly structures and shapes of mechanical structures, and design patents cover new designs, shapes, patterns, or colors, which are rich in an aesthetic appeal and are important for industrial application. An invention patent in China corresponds to the utility patent in the United State. Similar to those required in other major patent processes in the world, applicants of invention patents must submit relevant documents such as a clear and comprehensive description of the invention and reference materials so that an examiner may carry out the 'Substantive Examination' of the application…"

We will report the impact of tariffs on all three types of patent filings. We note that in fact the number of enterprises that do file patents in our sample period only account for a small fraction of all establishments. While the percentage has been growing, by the end of our sample period in 2007 it was still the case that less than 5 percent of enterprises had filed patents in China. However, it is still interesting to note, as reported by Fang, He and Li (2016), that the total volume of patent filings in China has increased rapidly and now exceeds the number for the United States. Our results, which replace TFP as a dependent variable with patent filings but keep otherwise the same specification, are reported in Table 6.

All the specifications in Table 6 use the same instrumental variable strategy employed in the earlier tables. More specifically, we instrument the log levels of tariffs with their initial level at the beginning of the sample period, a WTO dummy, and the interaction of the WTO dummy and the three initial tariff levels for final-goods tariffs, input tariffs, and backward tariffs. The first column of Table 6 reports the determinants of total patent filings, where the three kinds of patents are summed for each year and establishment. The results suggest that the number of patent filings are positively and significantly correlated with the share of exports in sectoral output, negatively correlated with public sector ownership, positively correlated with final demand for an establishments inputs by foreign owned enterprises, and negatively correlated with both final-goods tariffs and backward tariffs. The last two results are those we are particularly interested in, although the other significant results are of interest in their own right.

The coefficients on both final-goods tariffs and backward tariffs are negative, indicating that lower tariffs are associated with a higher probability of patent filings. However, the point estimates are only significant for final-goods tariffs. Since the standard deviation of log final tariffs (log backward tariffs) is .5 (.43) in our sample, and the coefficients on final tariffs range from -0.09 to -1.7, the coefficients suggest that one standard deviation reduction in final-goods tariffs would increase patent filings by between 0.04 (small) to 0.8 (large). This compares favorably to the patent mean of 0.6 patents per firm.

If we decompose patent filings into the three different types, then the results suggest that all types of patents are significantly associated with tariff changes. The largest effects are associated with establishments that do not change sectoral affiliation (column 5), indicating that Brandt et al (2017)'s intuition to focus on these sets of firms is supported by the evidence on patent filings. The evidence on patent filings in Table 6 is reassuring in that patent filings are pure measures of innovative activity and not associated with spurious changes in markups that might affect measures like TFP. The results are also reassuring for other variables, indicating significant association between patent activity and exporting and foreign investment.

To summarize, both the evidence on patent filings and sector shifts is consistent with the model, with firms investing in innovation in order to escape competition brought on by lower tariffs. In the case of sectoral shifts, we see that the small fraction of firms that do change sectors move to more skilled intensive products as final-goods tariffs fall. The evidence is consistent with the patent filings, which show that for those establishments remaining in the same sector, they respond to higher final goods competition resulting from lower tariffs by filing more patents.

While the evidence is clear and consistent for final goods, the results on mechanisms are less obvious for suppliers. The evidence suggests that a fall in backward tariffs is associated with sectoral shifts towards less (not more) skill-intensive goods. While the evidence on patent filings does suggest greater filings when backward tariffs fall, the results are significant at conventional levels.

6 Concluding Comments

In this paper, we identify a new source of productivity gains from trade reform: final-goods tariff changes feed back to input suppliers, creating "backward linkages." For China, backward linkages are the biggest source of productivity gains. Our results show that this is partly explained by the fact that final goods TFP increases are offset by markup reductions in final goods sectors.

Our explanation for our findings is formalized in the theoretical model. In the model, firms choose to invest in product differentiation in order to escape competition. Markups in the final goods sectors fall, consistent with the evidence presented in the paper. As firms upgrade through differentiating their products, they demand more differentiated inputs from their suppliers. Consequently, innovation spill over to domestic suppliers through backward linkages.

Our empirical work provides support for the mechanism: as tariffs fall, final goods providers increase patent filings and upgrade to higher skill intensive sectors.

References

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

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

[3] Aghion, P., R. Griffith (2008) *Competition and growth: reconciling theory and evidence* MIT press, Cambridge, MA.

[4] Amiti, M., J. Konings (2007) "Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia" *The American Economic Review* **97.5**: 1611-1638.

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

[6] Attanasio, O., P. Goldberg, N. Pavcnik (2004), "Trade Reforms and Wage Inequality in Colombia," *Journal of Development Economics*, **74**, 331-366.

[7] Bernard, A. B., J. B. Jensen, S. J. Redding, P. K. Schott (2007), "Firms in International Trade," *Journal of Economic Perspectives*, **21**, 105-130.

[8] Bloom, N., Manova, K., Van Reenen, J., Sun, S., Yu, Z. (2016) "Managing Trade: Evidence from China and the US." *mimeo*, Oxford University.

[9] Brandt, L., Van Biesebroeck, J., Wang, L., Zhang, Y. (2017) "WTO accession and performance of Chinese manufacturing firms," *mimeo*, University of Toronto.

[10] Bustos, P. (2011), "Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *The American Economic Review*, **101**, 304-340.

[11] De Loecker, J., and F. Warzynski (2012) "Markups and firm-level export status" *The American Economic Review* **102.6**: 2437-2471.

[12] Du, L., A. Harrison, G. H. Jefferson (2012) "Testing for horizontal and vertical foreign investment spillovers in China, 19982007" *Journal of Asian Economics* **23.3**: 234-243.

[13] Eslava, M., A. C. Fieler, D. Yi Xu. (2015) "(Indirect) Input Linkages", *The American Economic Review Papers and Proceedings* **105** 662-666.

[14] Fieler, A. C., M. Eslava, D. Yi Xu. (2016) "Trade, Quality Upgrading, and Input Linkages: Theory and Evidence from Colombia", *mimeo*, University of Pennsylvania.

[15] Goldberg, P., A. Khandelwal, N. Pavcnik, P. Topalova (2010), "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India," *Quarterly Journal of Economics*, **125**, 1727-1767

[16] Gopinath, G., B. Neiman (2014) "Trade adjustment and productivity in large crises", *The American Economic Review* **104**, 793-831.

[17] Holmes, T. J., J. A. Schmitz (2010), "Competition and Productivity: A Review of Evidence," *Annual Review of Economics*, **2**, 619-642.

[18] Hottman, C., S. J. Redding, D. E. Weinstein (2016) "Quantifying the sources of firm heterogeneity," *Quarterly Journal of Economics*, **131**, 1291-1364.

[19] 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**, 605-627.

[20] Kee, H. L., H. Tang (2015) "Domestic Value Added in Exports: Theory and Firm Evidence from China" *The American Economic Review*, **106**, 1402-1436.

[21] Khandelwal, A. (2010) "The long and short (of) quality ladders" *The Review of Economic Studies* **77.4**: 1450-1476.

[22] Kugler, M., E. Verhoogen (2012), "Prices, Plants and Product Quality," *The Review of Economic Studies*, **79**, 307-339.

[23] Lileeva, A., D. Trefler (2010), "Improved Access to Foreign Markets Raises Plant-Level Productivity...For Some Plants," *Quarterly Journal of Economics*, **125**, 1051-1099.

[24] Melitz, M. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, **71**, 1695-1725.

[25] Olley, S., and A. Pakes (1996), "The dynamics of productivity in the telecomunications equipment industry." *Econometrica* **64**: 1263-97.

Basic Regressions of Productivity Determinants
OLS and IV Results
Table 1

	OLS		IV		OLS		IV	
	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all
lnTariff	0.0454	0.0628	-0.0299***	0.154***	0.0505	0.0741	-0.0292***	0.158***
	(0.0554)	(0.0562)	(0.00476)	(0.00463)	(0.0575)	(0.0591)	(0.00530)	(0.00519)
lnBackward Tariff	-0.102*	-0.0961**	-0.115***	-0.125***	-0.124**	-0.115**	-0.175***	-0.169***
	(0.0532)	(0.0470)	(0.00548)	(0.00534)	(0.0523)	(0.0464)	(0.00647)	(0.00634)
lnInputTariff	0.0216	-0.00146	0.0426***	-0.0430***	0.0189	-0.00326	0.0397***	-0.0457***
	(0.0141)	(0.00998)	(0.00256)	(0.00250)	(0.0135)	(0.0104)	(0.00304)	(0.00297)
index_subsidy	0.00906***	0.0123***	0.00912***	0.0122***	0.00735***	0.00999***	0.00737***	0.00969***
	(0.00184)	(0.00168)	(0.00118)	(0.00115)	(0.00219)	(0.00190)	(0.00146)	(0.00143)
index_tax	0.0214***	0.0219***	0.0215***	0.0218***	0.0214***	0.0221***	0.0214***	0.0220***
	(0.000851)	(0.000898)	(0.000718)	(0.000700)	(0.000822)	(0.000881)	(0.000830)	(0.000813)
index_interest	-0.0134***	-0.0153***	-0.0133***	-0.0154***	-0.0155***	-0.0171***	-0.0153***	-0.0174***
	(0.00163)	(0.00144)	(0.000826)	(0.000805)	(0.00166)	(0.00142)	(0.000967)	(0.000947)
exportshare_sector	0.662***	0.359**	0.732***	0.304***	0.835***	0.502**	0.945***	0.462***
	(0.174)	(0.138)	(0.0105)	(0.0103)	(0.237)	(0.197)	(0.0135)	(0.0132)
Stateshare	-0.000720	-0.000576	-0.00142	0.000140	0.00149	0.00211	0.000588	0.00314
	(0.00388)	(0.00393)	(0.00341)	(0.00332)	(0.00481)	(0.00468)	(0.00390)	(0.00382)
Horizontal FDI	0.147	0.312*	0.159***	0.303***	0.156	0.327*	0.174***	0.328***
	(0.176)	(0.178)	(0.0119)	(0.0116)	(0.183)	(0.191)	(0.0144)	(0.0141)
Backward FDI	0.960	1.983***	1.063***	1.939***	0.680	1.800***	0.868***	1.792***
	(0.731)	(0.566)	(0.0355)	(0.0346)	(0.735)	(0.581)	(0.0426)	(0.0417)
Forward FDI	0.526***	0.545***	0.440***	0.647***	0.514**	0.520***	0.412***	0.603***
	(0.188)	(0.111)	(0.00925)	(0.00901)	(0.200)	(0.121)	(0.0110)	(0.0108)
Observations	991,440	991,440	991,440	991,440	785,025	785,025	785,025	785,025

Notes: Robust standard errors in parentheses. Asterisks indicate significance as follows: *** indicates $p<0.01$, ** $p<0.05$, * $p<0.1$. For IV estimates, the instruments include initial tariffs (final products, backward and forward) and a WTO dummy equal to one when China entered the WTO. All specifications include firm fixed effects and time dummies. Other controls also included but not reported here.

Table 2
Comparing Our Results with Brandt et al
(With and without Firms that Change Sectors)

	Only Establishments remaining in the Same 2 Digit Sector over the Sample Period (Replicating Brandt et al)				Only Establishments that Change from One 2 Digit Sector to Another over the Sample Period			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	IV	IV	OLS	OLS	IV	IV
VARIABLES	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all	TFP_OP_all	TFP_olsFE_all
lnTariff	-0.0634**	-0.0696**	-0.0732***	-0.0254***	0.226*	0.234**	0.0494***	0.219***
	(0.0293)	(0.0272)	(0.00800)	(0.00791)	(0.116)	(0.0933)	(0.00864)	(0.00738)
lnBackward Tariff	-0.0547*	-0.0510	-0.187***	-0.174***	-0.217*	-0.166*	-0.188***	-0.131***
	(0.0303)	(0.0326)	(0.0142)	(0.0140)	(0.122)	(0.0866)	(0.00828)	(0.00707)
lnInputTariff	0.00953	0.00676	0.0429***	-0.0116**	0.0402	-0.0214	0.0417***	-0.0420***
	(0.00951)	(0.0106)	(0.00595)	(0.00589)	(0.0399)	(0.0252)	(0.00408)	(0.00349)
index_subsidy	0.0140***	0.0139***	0.0138***	0.0135***	0.00212	0.00698	0.00128	0.00701*
	(0.00205)	(0.00185)	(0.00119)	(0.00118)	(0.00475)	(0.00419)	(0.00421)	(0.00360)
index_tax	0.0222***	0.0219***	0.0221***	0.0217***	0.0221***	0.0221***	0.0224***	0.0223***
	(0.00104)	(0.00108)	(0.000720)	(0.000713)	(0.00205)	(0.00199)	(0.00275)	(0.00235)
index_interest	-0.0148***	-0.0139***	-0.0148***	-0.0140***	-0.0187***	-0.0216***	-0.0183***	-0.0216***
	(0.00130)	(0.00113)	(0.000832)	(0.000824)	(0.00588)	(0.00480)	(0.00308)	(0.00263)
exportshare_sector	0.313*	0.251*	0.411***	0.338***	0.703***	0.302*	0.810***	0.270***
	(0.174)	(0.150)	(0.0182)	(0.0180)	(0.242)	(0.159)	(0.0196)	(0.0167)
Stateshare	0.000275	-0.000374	0.000526	-0.000100	-0.000110	-0.00382	-0.00297	-0.00378
	(0.00351)	(0.00353)	(0.00339)	(0.00335)	(0.0131)	(0.0132)	(0.0138)	(0.0117)
Horizontal FDI	0.113	0.235	0.116***	0.276***	0.0586	0.245	0.157***	0.260***
	(0.151)	(0.167)	(0.0170)	(0.0168)	(0.271)	(0.214)	(0.0244)	(0.0208)
Backward FDI	1.225**	1.518**	1.691***	1.723***	1.440	2.300***	1.340***	2.207***
	(0.584)	(0.655)	(0.0758)	(0.0751)	(0.931)	(0.622)	(0.0613)	(0.0523)
Forward FDI	0.394***	0.317*	0.386***	0.339***	0.788***	0.793***	0.605***	0.805***
	(0.148)	(0.171)	(0.0149)	(0.0148)	(0.253)	(0.134)	(0.0174)	(0.0148)
Observations	871,817	871,817	871,817	871,817	119,623	119,623	119,623	119,623

Notes: Robust standard errors in parentheses. Asterisks indicate significance as follows: *** indicates p<0.01, ** p<0.05, * p<0.1. For IV estimates, the instruments include initial tariffs (final products, backward and forward) and a WTO dummy equal to one when China entered the WTO. All specifications include firm fixed effects and time dummies. Other controls also included but not reported here. This Table includes the same specifications as in Table 1 but splits the sample into two groups. The first four columns exclude establishments that change their main sector affiliation during the sample period. The last four columns only include establishments that change sectoral affiliation. Brandt et al use the sample that does not have changes in sector affiliation (the first four columns).

Table 3
Accounting Margins and Tariffs

Dependent Variable is Reported Gross Profit Margin as a Share of Sales (ROS)

	All Firms Excluding Multinationals and SOEs		Only Non-Exporters		Only Exporting Firms	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ROS	ROS	ROS	ROS	ROS	ROS
lnTariff	0.359**	0.544***	0.464**	0.788***	0.0481	-0.480*
	(0.176)	(0.106)	(0.192)	(0.120)	(0.117)	(0.257)
lnBackward Tariff	-0.183	0.215*	-0.211	0.308**	-0.146	-0.145
	(0.148)	(0.118)	(0.172)	(0.147)	(0.162)	(0.217)
lnInputTariff	0.0191	0.0649	0.0112	0.0367	0.0515	0.119
	(0.0446)	(0.0581)	(0.0463)	(0.0713)	(0.0683)	(0.111)
Observations	990,277	990,277	784,041	784,041	206,236	206,236
	(0.0568)	(0.0273)	(0.0666)	(0.0348)	(0.0639)	(0.0431)
index_tax	2.944***	2.944***	3.027***	3.028***	2.502***	2.502***
	(0.141)	(0.0167)	(0.158)	(0.0197)	(0.119)	(0.0326)
index_interest	0.0364	0.0364*	0.0414	0.0411*	0.0252	0.0237
	(0.0302)	(0.0192)	(0.0327)	(0.0230)	(0.0608)	(0.0359)
stateshare	-0.298**	-0.294***	-0.370***	-0.365***	-0.168	-0.167
	(0.121)	(0.0792)	(0.131)	(0.0929)	(0.263)	(0.159)
Horizontal FDI	-1.203*	-1.541***	-1.584*	-2.105***	-0.770	-0.563
	(0.620)	(0.259)	(0.817)	(0.319)	(0.547)	(0.492)
Backward FDI	-0.751	-1.791**	-0.0226	-1.353	-0.138	0.541
	(1.723)	(0.819)	(2.311)	(1.009)	(1.445)	(1.527)
Forward FDI	0.173	0.472**	0.516	1.038***	-0.0460	-0.615
	(0.367)	(0.214)	(0.491)	(0.261)	(0.353)	(0.429)
Observations	990,277	990,277	784,041	784,041	206,236	206,236

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4

Output and Tariffs

	All Firms (Excluding Multinationals and SOEs)		Non_Exporters Only	
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
VARIABLES	logY	logY	logY	logY
lnTariff	-0.0335	0.0704***	-0.0207	0.0982***
	(0.0230)	(0.00867)	(0.0237)	(0.0100)
lnBackwardTariff	0.0422*	-0.0248***	0.0105	-0.000654
	(0.0245)	(0.00929)	(0.0227)	(0.0111)
lnInputTariff	-0.00844	-0.0492***	-0.00599	-0.0510***
	(0.0110)	(0.00423)	(0.00933)	(0.00507)
index_subsidy	0.0969***	0.0967***	0.0823***	0.0821***
	(0.00630)	(0.00248)	(0.00718)	(0.00310)
index_tax	0.0661***	0.0660***	0.0683***	0.0682***
	(0.00256)	(0.00151)	(0.00301)	(0.00176)
index_interest	-0.0998***	-0.100***	-0.110***	-0.111***
	(0.00346)	(0.00174)	(0.00341)	(0.00205)
exportshare_sector	0.0239	-0.00917	-0.141	-0.244***
	(0.0876)	(0.0208)	(0.102)	(0.0274)
Stateshare	0.0417***	0.0426***	0.0389***	0.0403***
	(0.00987)	(0.00718)	(0.0110)	(0.00827)
Observations	991,440	991,440	785,025	785,025
Firm FE?	Y	Y	Y	Y
Sector Fixed Effects?	N	N	N	N

Robust standard errors in parentheses. Dependent variable is the log of real output. All specifications include firm fixed effects and time effects. Instruments in the IV specifications for lnTariff, ln backward Tariff, and ln input tariff include initial tariff, a WTO dummy, and the WTO dummy interacted with the initial tariff. Other controls included (like Horizontal FDI, Backward FDI, and Forward FDI) but not reported here.

*** p<0.01, ** p<0.05, * p<0.1

Table 5
Movements to Sectors with Higher Skilled Worker Share Based on 2004 survey

	All Enterprises (Excluding SOEs and Multinationals)		Only Non-Exporting Enterprises		Only Exporting Enterprises	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Sector Rank	Sector Rank	Sector Rank	Sector Rank	Sector Rank	Sector Rank
	OLS	IV	OLS	IV	OLS	IV
lnTariff	-16.61***	-34.93***	-14.04**	-29.83***	-23.55***	-54.80***
	(5.549)	(0.469)	(5.463)	(0.514)	(6.627)	(1.334)
lnBackward Tariff	16.10***	25.45***	14.02**	24.56***	19.87***	24.19***
	(5.340)	(0.540)	(5.577)	(0.628)	(5.598)	(1.220)
lnInputTariff	-4.475**	-9.277***	-4.142*	-9.499***	-5.814**	-7.878***
	(2.227)	(0.253)	(2.112)	(0.295)	(2.607)	(0.590)
index_subsidy	0.504***	0.546***	0.605**	0.694***	0.347	0.313
	(0.189)	(0.116)	(0.241)	(0.142)	(0.246)	(0.210)
index_tax	0.0658	0.105	0.128	0.180**	-0.296	-0.324**
	(0.104)	(0.0708)	(0.0992)	(0.0806)	(0.177)	(0.159)
index_interest	-0.421***	-0.391***	-0.455***	-0.402***	-0.420**	-0.499***
	(0.133)	(0.0815)	(0.135)	(0.0938)	(0.204)	(0.175)
exportshare_sector	-186.7***	-182.6***	-197.9***	-192.4***	-171.9***	-160.6***
	(23.69)	(1.038)	(26.14)	(1.311)	(22.27)	(2.091)
Stateshare	-0.151	-0.397	-0.223	-0.501	0.438	0.395
	(0.487)	(0.336)	(0.546)	(0.379)	(0.843)	(0.775)
Horizontal FDI	63.32**	67.62***	64.58**	71.06***	62.51*	55.88***
	(29.08)	(1.171)	(28.86)	(1.395)	(31.59)	(2.475)
Backward FDI	479.7***	465.9***	498.0***	471.0***	439.3***	473.9***
	(103.7)	(3.501)	(115.5)	(4.134)	(86.41)	(7.591)
Forward FDI	-43.50*	-54.68***	-50.37*	-59.35***	-26.49	-49.12***
	(22.41)	(0.912)	(25.34)	(1.071)	(18.83)	(2.100)
Observations	991,441	991,441	785,026	785,026	206,415	206,415
Firm FE?	Y	Y	Y	Y	Y	Y
Sector Fixed Effects?	N	N	N	N	N	N

Notes: Robust standard errors in parentheses with *** indicating p<0.01, ** indicating p<0.05, and * indicating p<0.1. The dependent variable in all specifications is the firm's sectoral ranking based on the sector reported by the firm in that year. The firm's sector of affiliation, which is the dependent variable, has been ranked with 1 using the most educated workers across all 450 sectors, and the ranking is based on a cross section of all firms in 2004.

Table 6

Patent filings as an Alternative Measure of Productivity at the Establishment Level

IV Estimates Using Same Instruments as Previous Tables

	Determinants of Patent Filings by Year at the Establishment Level (Total Patent Filings, Invention Patents, Utility Patents and Design Patents)					
VARIABLES	Total Patent Filings	Invention Patents	Utility Patents	Design Patents	Total Patent Filings	Total Patent Filings
					Only Establishments That Remain in the Same Sector	Only Establishments that Change Sector
lnTariff	-0.578***	-0.243*	-0.0861***	-0.249***	-1.682***	-0.0312
	(0.161)	(0.135)	(0.0279)	(0.0509)	(0.311)	(0.0669)
lnBackward Tariff	-0.304	-0.202	0.00862	-0.110*	-0.707	0.0552
	(0.186)	(0.155)	(0.0322)	(0.0586)	(0.546)	(0.0640)
lnInputTariff	0.270***	0.161**	0.0393***	0.0691**	1.158***	-0.0220
	(0.0870)	(0.0726)	(0.0151)	(0.0274)	(0.231)	(0.0316)
index_subsidy	-0.000153	-0.0706**	0.0275***	0.0429***	-0.00122	0.0121
	(0.0399)	(0.0333)	(0.00691)	(0.0126)	(0.0468)	(0.0326)
index_tax	0.0209	0.00178	0.00490	0.0142*	0.0283	-0.0149
	(0.0244)	(0.0203)	(0.00422)	(0.00768)	(0.0282)	(0.0212)
index_interest	0.0241	0.0389*	-0.0115**	-0.00330	0.0415	-0.0709***
	(0.0280)	(0.0234)	(0.00486)	(0.00884)	(0.0326)	(0.0238)
exportshare_sector	1.641***	0.831***	0.348***	0.461***	3.343***	-0.0134
	(0.357)	(0.298)	(0.0619)	(0.113)	(0.707)	(0.151)
Stateshare	-0.261**	-0.147	-0.0351*	-0.0789**	-0.279**	-0.122
	(0.116)	(0.0964)	(0.0200)	(0.0365)	(0.133)	(0.107)
Horizontal FDI	0.265	0.532	-0.115*	-0.152	-0.193	0.306
	(0.403)	(0.336)	(0.0698)	(0.127)	(0.661)	(0.189)
Backward FDI	3.222***	2.099**	0.294	0.829**	17.77***	-0.241
	(1.204)	(1.005)	(0.209)	(0.380)	(2.906)	(0.474)
Forward FDI	-0.852***	-0.549**	-0.0250	-0.279***	-0.871	-0.133
	(0.314)	(0.262)	(0.0543)	(0.0990)	(0.576)	(0.134)

Notes: Robust standard errors in parentheses with *** indicating p<0.01, ** indicating p<0.05, and * indicating p<0.1. All specifications include establishment fixed effects and year effects. The dependent variable in all specifications is a different measure of the number of patents filed at the establishment level. If no patents are recorded by SIPO then the dependent variable is set to zero.

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References to sections and equations that do not start with a letter all refer to the main text.

A Appendix to theory

A.1 Proof that $\pi_D \geq \pi_0$

We prove that, net of fixed costs, investment in differentiation is always profitable: $\pi_D \geq \pi_0$.

$$\begin{aligned}\pi_D(\phi) &\geq \frac{YP^{\eta-1}}{\epsilon_0}\left(\frac{\epsilon_0}{(\epsilon_0-1)\phi}\right)^{1-\eta} \\ &\geq YP^{1-\eta}\left(\frac{\epsilon_0}{(\epsilon_0-1)\phi}\right)^{1-\eta}\left(\frac{\epsilon_0}{(\epsilon_0-1)\phi P_0}\right)^{\eta-\sigma} = \pi_0(\phi)\end{aligned}$$

where all prices P and P_0 are calculated when the firm's price is $\frac{\epsilon_0}{(\epsilon_0-1)\phi}$. The first line comes from optimization—setting markup ϵ_D yields higher profits than ϵ_0 if the firm is differentiated. The second line comes because the added term, $\left(\frac{\epsilon_0}{(\epsilon_0-1)\phi P_0}\right)^{\eta-\sigma} \leq 1$, since $\frac{\epsilon_0}{(\epsilon_0-1)\phi P_0} > 1$ and $\eta < \sigma$. The two operating profits are equal only when there are no other firms in nest 0.

Small firm's case In the case of small firms where markups are constant,

$$\begin{aligned}\pi_0 &= \frac{1}{\sigma}\left(\frac{\sigma}{(\sigma-1)\phi}\right)^{1-\sigma} P_0^{\sigma-\eta}P^{\eta-1} \\ &\leq \frac{1}{\sigma}\left(\frac{\sigma}{(\sigma-1)\phi}\right)^{1-\eta} P^{\eta-1} \\ &< \frac{1}{\eta}\left(\frac{\eta}{(\eta-1)\phi}\right)^{1-\eta} P^{\eta-1} = \pi_D\end{aligned}$$

where the first inequality comes from $P_0 \leq \left(\frac{\sigma}{(\sigma-1)\phi}\right)$ and the second inequality from optimization under differentiation—setting markup ϵ_D yields strictly higher profits than setting it ϵ_0.

A.2 Proof of claim 3, section 3.4

Claim 3. Profit from investing decreases in $\frac{P_{-i0}}{P_{-i}}$. *Proof.* Profit π_D under differentiation depends only on P_{-i}. So, we need to prove that π_0 is decreasing in $\frac{P_{-i0}}{P_{-i}}$. By the envelope theorem, $\frac{d\pi_0}{d(P_{-i0}/P_{-i})} = \frac{\partial\pi_0}{\partial(P_{-i0}/P_{-i})}$. So, we rewrite profit π_0 as a function of $r = \frac{P_{-i0}}{P_{-i}}$, $q = \frac{p}{P_{-i}}$ and P_{-i}:

$$\pi_0 = Y \left[\frac{\left(P_{-i0}^{1-\sigma} + p^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}}{P_{-i}^{1-\eta} - P_{-i0}^{1-\eta} + \left(P_{-i0}^{1-\sigma} + p^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}} \right] \frac{p^{1-\sigma}(p-c)}{P_{-i0}^{1-\sigma} + p^{1-\sigma}}$$
$$\pi_0 = Y P_{-i}^{\sigma-1} \left[\frac{\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}}{1 - r^{1-\eta} + \left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}} \right] \frac{p^{1-\sigma}(p-c)}{r^{1-\sigma} + q^{1-\sigma}}$$

where the term $P_{-i}^{1-\eta} - P_{-i0}^{1-\eta} = \sum_{n\neq 0, n\in N} P_n^{1-\eta}$ in the first line is the price of differentiated goods, and $(P_{-i0}^{1-\sigma} + p^{1-\sigma})^{\frac{1}{1-\sigma}} = P_0$ is the price index of non-differentiated goods including the firm itself.

We first derive some auxiliary derivatives:

$$\frac{\partial}{\partial r}\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}} = (1-\eta)\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}-1} r^{-\sigma}$$

and

$$\frac{\partial}{\partial r}\left[\frac{\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}}{1 - r^{1-\eta} + \left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}} \right]$$
$$= \left[\frac{(1-\eta)(1-r^{1-\eta})\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}-1} r^{-\sigma}}{[1 - r^{1-\eta} + \left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}]^2} \right]$$

Finally,

$$\begin{aligned}
\frac{\partial\pi_0}{\partial r} &= \frac{\pi_0}{r}\left[(1-\eta)(1-S_0)(1-s_0) + (\sigma-1)(1-s_0)\right] \\
&= \frac{\pi_0(1-s_0)}{r}\left[(1-\eta)(1-S_0) + (\sigma-1)\right] \\
&\geq \frac{\pi_0(1-s_0)}{r}(\sigma-\eta) \geq 0 \\
\text{where} \quad S_0 &= \frac{\left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}}{[1 - r^{1-\eta} + \left(r^{1-\sigma} + q^{1-\sigma}\right)^{\frac{1-\eta}{1-\sigma}}]} \\
s_0 &= \frac{q^{1-\sigma}}{r^{1-\sigma} + q^{1-\sigma}}
\end{aligned} \tag{A.1}$$

S_0 is the market share of nest zero in total spending Y, and s_0 recall is the market share of the firm within nest 0. The inequality follows because $s_0, S_0 \in [0,1]$ and $\sigma > \eta$. The derivative is zero only if the firm has the monopoly in nest 0, $s_0 = 1$. ■

A.3 Effect of P_{-i} on firm's choices

This appendix proves that the effect of P_{-i} on firm's choices follows the patterns illustrated in figure 2: (i) P_{-i} increases π_0 and π_D so that it shifts the exit curve to the left. (ii) P_{-i} increases the difference $(\pi_D - \pi_0)$ so that the set of investing firms expands. These results are proven for any given ratio $r = \frac{P_{-i0}}{P_{-i}}$.

We write operating profits π_0 and π_D as functions of P_{-i}, r and the firm's own price p, and we take partial derivatives with respect to P_{-i}. By the envelope theorem, these partial derivatives equal the total derivatives: $\frac{d\pi_0}{dP_{-i}} = \frac{\partial \pi_0}{\partial P_{-i}}$ and $\frac{d\pi_D}{dP_{-i}} = \frac{\partial \pi_D}{\partial P_{-i}}$. We prove claims (i) and (ii) by deriving sign of these derivatives.

With differentiation

$$\pi_D = \frac{p^{-\eta}}{P_{-i}^{1-\eta} + p^{1-\eta}}(p - c)$$

Taking derivatives, we get

$$\frac{\partial \pi_D}{\partial P_{-i}} = (\eta - 1)\frac{\pi_D}{P_{-i}}(1 - s_D)$$

where s_D is the market share of the firm in total spending Y. We add subscript D to make explicit that the firm's market share is generally different under differentiation from non-differentiation.

Without differentiation,

$$\pi_D = Y P_{-i}^{\sigma-1} \left[\frac{(r^{1-\sigma} + (p/P_{-i})^{1-\sigma})^{\frac{1-\eta}{1-\sigma}}}{1 - r^{1-\eta} + (r^{1-\sigma} + (p/P_{-i})^{1-\sigma})^{\frac{1-\eta}{1-\sigma}}} \right] \frac{p^{1-\sigma}(p - c)}{r^{1-\sigma} + (p/P_{-i})^{1-\sigma}}$$

Taking derivatives, we get

$$\begin{aligned} \frac{\partial \pi_0}{\partial P_{-i}} &= \frac{\pi_0}{P_{-i}} \left[(\sigma - 1) + (\eta - 1)(1 - S_0)s_0 + (\sigma - 1)s_0 \right] \\ &= \frac{\pi_0}{P_{-i}} \left[(\sigma - 1)(1 - s_0) + (\eta - 1)(1 - S_0)s_0 \right] \end{aligned}$$

where as before S_0 is spending on nest 0 as a share of total spending, defined in equation (A.1).

(i) P_{-i} increases π_0 and π_D. Both $\frac{\partial \pi_0}{\partial P_{-i}} > 0$ and $\frac{\partial \pi_D}{\partial P_{-i}} > 0$ since $\sigma > 1$ and $\eta > 1$ and market shares $s_D, s_0, S_0 \in (0, 1)$.

(ii) P_{-i} increases the difference $(\pi_D - \pi_0)$ Operating profits is sales over the elasticity of demand: $\pi = \frac{Ys}{\epsilon}$. Using the price strategy of firms and $s = S_0 s_0$ for the non-differentiated firm, we have

$$
\begin{aligned}
P_{-i}\frac{\partial(\pi_D-\pi_0)}{\partial P_{-i}} &= (\eta-1)(1-s_D)\pi_D - [(\sigma-1)(1-s_0)+(\eta-1)(1-S_0)s_0]\pi_0 \\
&= \frac{(\eta-1)(1-s_D)s_D}{\eta(1-s_D)} - \left[\frac{(\sigma-1)(1-s_0)+(\eta-1)(1-S_0)s_0}{\sigma(1-s_0)+\eta s_0(1-S_0)}\right]s \\
&= \frac{\eta-1}{\eta}s_D - \left[\frac{\sigma(1-s_0)+\eta(1-S_0)s_0-(1-s_0)-(1-S_0)s_0}{\sigma(1-s_0)+\eta s_0(1-S_0)}\right]s \\
&\geq \frac{\eta-1}{\eta}s_D - \frac{\eta-1}{\eta}s > 0
\end{aligned}
$$

where the last inequality follows because sales with differentiation is greater than without.

■