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ESCAPING IMPORT COMPETITION AND DOWNSTREAM TARIFFS

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ABSTRACT

We propose and provide evidence for a new source of gains from trade: Firms invest in product differentiation to escape import competition. In the data and in the model, these investments are associated with increases in measured productivity, introduction of new goods, and shifts to skill-intensive sectors. Investment in differentiation downstream leads upstream firms to also invest in differentiation. For China, these “downstream tariff” reductions increase the measured productivity of suppliers by more than they increase the productivity of firms directly competing with imports.

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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 explaining the positive effect of reductions to trade barriers on 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."[1]

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 augment a standard regression of firm productivity on tariffs by considering tariff changes in the firm's own sector (output tariffs), its upstream sector (input tariffs), and its downstream sector (downstream tariffs). The first two tariff measures are common in the literature, while the concept of downstream tariffs is novel. Using firm-level data from China spanning the years of its accession to the WTO in 2001, we provide evidence that reductions in all three tariff measures increase firm productivity, and that the effect of downstream tariffs is larger than the effect of output tariffs. A literature pioneered by Javorcik (2004) and Blalock and Gertler (2008) identifies vertical linkages as the primary source of productivity spillovers from multinational firms, and we bring these insights to the context of a trade reform.

To explain this positive effect of international trade on the productivity of import competing firms and their suppliers, we develop a model where firms invest to escape import competition. A firm that invests creates a new market niche where it enjoys greater monopoly power. In our preferred interpretation, Chinese firms invest in differentiation by tailoring their goods to domestic tastes or improving non-tradable services offered with products. For example, the cell phone company Symbio prevented the expansion of Apple in China by tailoring its services to the Chinese market. Shortly after the Chinese WTO accession, the automobile company Chery introduced several new, small car models with a

[1] See Holmes and Schmitz (2010) and Steinwender (2015) for theories based on x-inefficiencies and evidence from case studies.

much greater variety of optional features, and it made replacement parts readily available. One can interpret the last two changes as a provision of non-tradable services since it is difficult for firms producing cars abroad to offer customized car features and a wide range of replacement parts.

Mechanically, the model features heterogeneous firms and variable markups with nested CES preferences à la Atkeson and Burstein (2008). Each firm chooses between (1) producing a variety in a less-differentiated nest where the elasticity of substitution between varieties is high and (2) paying a fixed cost to invent a new nest with 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 impact of competition on innovation found in Aghion et al. (2005) and Aghion et al. (2015). Our use of CES preferences brings their results closer to data and to standard trade literature.[2]

In mapping the model to data, we assume that a reduction in a sector-specific tariff increases competition in the less-differentiated nest. In line with the examples above, the interpretation is that differentiated goods are less tradable, because they cater to Chinese tastes or are enhanced with non-tradable services. Under this assumption, tariff reductions increase investments in product differentiation and decrease markups for a given level of differentiation. This result implies that tariffs have an ambiguous effect on the measured productivity of import-competing firms.

Assuming that differentiated downstream firms use only differentiated inputs, import competition downstream decreases the market for non-differentiated domestic inputs. As a result, upstream firms also invest. But their markups are not as affected. So, in line with the data, the model predicts that the effect of tariff reductions on productivity is larger for upstream firms than for firms directly competing with imports. We also prove that firms in the market equilibrium under invest in differentiation relative to the planner's preferred choice. So, the trade-induced investment in product differentiation constitutes a gain from trade not previously identified in the literature. A simple calibration of the model shows that this new welfare gain may be quite large.

We provide further evidence for the theory in the case of China. Between 1998 and 2007, China embarked on a significant trade reform. Average tariffs on manufacturing

[2]Other related models are those of variable markups and international trade, such as Bernard et al. (2003) and Melitz and Ottaviano (2008).

in China fell from 43 percent in 1994 to 9.4 percent in 2004, following China's accession to the WTO in 2001. Imports as a share of GDP doubled from 14% prior to WTO entry to 28% within several years. These significant changes in tariff policy combined with China's WTO entry allow us to identify the impact of domestic trade reforms on Chinese manufacturing firms. 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. We 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 and Pakes (1996) to construct measures of total factor productivity (TFP).

For corroborating evidence on investment in differentiation, we show that import-competing firms and their suppliers respond to tariff cuts by introducing new products and systematically switching into sectors requiring more skilled labor. The introduction of new products challenges recent models of multiproduct firms where tighter competition leads firms to drop their least-productive varieties. Switching to more skill-intensive sectors is inconsistent with the classic Heckscher-Ohlin model where import competition should push China toward its unskill-intensive comparative advantage sectors.[3] The findings above that tariff reductions increase TFP also challenge a large class of models in international trade where productivity is driven by economies of scale.[4] In these models, an increase in competition decreases sales and the incentives for firms to improve productivity. Although there may be alternative explanations, taken together, our empirical results support the proposed mechanism of investment in differentiation.

In Section 2 we develop the model. Section 3 begins by reporting reduced-form results on the productivity responses to falling tariffs. We analyze the effect of tariff reductions on a firm's own sector, on its upstream sectors and on its downstream sectors. We find significant gains to productivity (TFP) from tariff reforms in all three types of tariffs. We then explore the mechanisms underlying the TFP results, reporting empirical results for accounting margins, product shifting and further extensions. We also perform a number of robustness tests on the empirical results. Section 4 brings the data and model together in a stylized calibration exercise. We conclude in Section 5.

[3]For examples of models with multi-product firms, see Bernard et al. (2011) and Mayer et al. (2014). The findings on the skill intensity of input suppliers is consistent with evidence in Kugler and Verhoogen (2011) and Fieler et al. (2018) that skill-intensive firms use more skill-intensive inputs. The firm variables that we analyze, including the new-goods margin, have been used to analyze the effects of imported inputs on firms—e.g., Goldberg et al. (2009), Goldberg et al. (2010) , Halpern et al. (2015).

[4]See, for example, Bustos (2011), Caliendo and Rossi-Hansberg (2012), Helpman et al. (2017).

2 Theory

We study the effect of import competition on investment in product differentiation. Investment allows the firm to insulate itself from competition by creating a new market niche where it can enjoy greater monopoly power. Section 2.1 presents a model with only final-goods firms to focus on the effect of tariffs on firms directly competing with imports. Section 2.2 adds input suppliers to the model. All proofs are in the Appendix. The main results are robust to a series of extensions of the model described at the end of this section. Extensions include imitation, increasing cost of differentiation, and a general equilibrium variant of the model.

2.1 A Model with Only Final-Goods Production

There is a fixed and finite set of firms that compete à la Bertrand. Firms have heterogeneous productivities. Each firm has a unique variety. Firms may exit or pay a fixed cost to produce. If the firm produces, it chooses between two levels of differentiation. Less-differentiated varieties face a higher price elasticity of demand but have lower (variable or fixed) costs than the more differentiated varieties. To avoid cumbersome language, we refer to the less-differentiated varieties as "non-differentiated" and to the more-differentiated as "differentiated" although all varieties are differentiated in the sense of facing a finite elasticity of demand. Given the empirical focus on import competition, domestic firms do not export in the sector analyzed.

2.1.1 Demand

Total spending is inelastic and normalized to one. A continuum of varieties is classified into nests. Spending on a variety with price p in nest n follows a nested CES structure:

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

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

$$\overline{P} = \left[\int P_n^{1-\eta} dn\right]^{\frac{1}{1-\eta}},$$

P_n is the price index of nest n and $\overline{P}$ is the overall price index. Assume that the elasticity of substitution within nests is larger than across nests: $\sigma > \eta > 1$.

There are two types of nests. Nest $\mathcal{O}$ contains all non-differentiated varieties and we denote its variables with a zero. When a firm has a differentiated variety, it is the single producer in its own nest. Then, $P_n = p$ and demand reduces to $x = (p/\overline{P})^{1-\eta}$. For simplicity, there is a continuum of nests and we take the overall price index $\overline{P}$ as exogenous. Under the interpretation that exogenous nests belong to other sectors, differentiated products compete more directly with firms in other sectors, and the assumption that $\overline{P}$ is exogenous is justified by the empirical analysis, which exploits cross-sectoral variation. The price of nests P_0 and P_n for the finite set of firms modeled is endogenous.

2.1.2 Technology

In addition to pricing, each firm decides between three discrete choices. If it exits, its profit is zero. If it produces, it chooses whether to invest in product differentiation or not. The fixed cost of production is f_0 if the firm does not invest, and it is f_D if the firm invests. Firm i's marginal cost is c_n/ϕ_i, where ϕ_i is firm-specific productivity. Input cost $c_n = c_0$ if the product is not differentiated and $c_n = c_D$ otherwise. The assumption that c_n is common to all firms implies that any productivity gain or loss associated with investment is common to all firms. As in Melitz (2003), c_n/ϕ_i is cost adjusted for quality. Throughout, we assume that $f_D > f_0$ although the propositions all hold if $f_D \leq f_0$ and $c_D > c_0$.

2.1.3 Equilibrium

The set of potentially active firms is exogenous. One can interpret this assumption as allowing for free entry and firm knowledge about their productivity prior to entry.[5] The price of foreign varieties and the productivity of each domestic firm are exogenous and known. Timing is as follows. In order of productivity, firms make their exit and investment decisions. Once these discrete choices are made, firms simultaneously set prices. We consider the unique subgame perfect equilibrium.[6]

[5]The assumption that the set of firms is exogenous implies that import competition decreases the domestic price index. Normally, in static models with free entry and without export expansion, foreign competition induces the exit of domestic plants and has no effect on the price index. Then, import competition has no effect on the behavior of surviving firms. An alternative is to introduce dynamics and sunk entry costs. With sunk costs, firms do not immediately exit with import competition and the price index temporarily decreases as in Alessandria et al. (2014).

[6]The timing of firms' discrete choices according to productivity is an equilibrium selection mechanism. It is well known (and easy to see) that multiple equilibria may arise when a finite set of large firms play simultaneously. But the timing here is such that, when more productive firms make their discrete choices, they fully anticipate the actions of their competitors. So they are effectively selecting among subgame equilibria. Since uniqueness holds in each stage of each subgame, the subgame perfect equilibrium is unique by backward induction. More precisely, equilibrium is unique up to a perturbation of the parameters since multiple equilibria arise whenever a firm is indifferent between two subgame perfect

2.1.4 Markups, Competition and Product Differentiation

To characterize the equilibrium, we focus on a firm's problem and omit the firm's subscript i. A firm in nest n chooses price p to maximize profit

$$\pi = \max_p \overline{P}^{\eta-1} P_n^{\sigma-\eta} p^{-\sigma}(p - c_n/\phi). \tag{2}$$

Following Atkeson and Burstein (2008), the firm's markup over marginal cost is $\epsilon/(\epsilon-1)$, where

$$\epsilon = \sigma(1-s) + \eta s \tag{3}$$

ϵ is the endogenous elasticity of demand with respect to price and s is the market share of the firm within its nest $s = (p/P_n)^{1-\sigma}$. Elasticity ϵ is a weighted average between the elasticity within the nest σ and the elasticity across nests η. If the firm invests, $P_n = p$, $s = 1$ and its demand elasticity is η. Otherwise, $P_n = P_0$.

The firm's operating profit with and without product differentiation is, respectively,

$$\begin{aligned} \pi_D &= \frac{\overline{P}^{\eta-1}}{\eta} \left(\frac{\eta c_D}{(\eta-1)\phi} \right)^{1-\eta} \\ \pi_0 &= \overline{P}^{\eta-1} \frac{P_0^{\sigma-\eta}}{\epsilon} \left(\frac{\epsilon c_0}{(\epsilon-1)\phi} \right)^{1-\sigma} \end{aligned} \tag{4}$$

The firm chooses $\max\{0, \pi_0 - f_0, \pi_D - f_D\}$. By backward induction, we can solve for each firm's discrete choice in all subgames, starting with the least productive firms. Throughout, we ignore the uninteresting decisions at indifference points.

Proposition 1 ***Exit.*** *There exists a unique $\tilde{\phi} > 0$ such that firms produce if and only if $\phi \geq \tilde{\phi}$. Cutoff $\tilde{\phi}$ is decreasing in $\overline{P}$, and increasing in costs c_D and c_0.*

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

The decision to invest, in contrast, is not monotonic in productivity. We characterize it as a function of the level of competition the firm faces, summarized by $\left(\phi, P_{-i0}, \overline{P}, c_0, c_D\right)$ where P_{-i0} is the price index that firm i would face if it did not invest in differentiation,

equilibria.

considering all other firms' responses to firm i's decision not to invest:

$$P_{-i0} = \left(\sum_{i' \neq i, i' \in \mathcal{O}(i)} p_{i'}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \tag{5}$$

where $\mathcal{O}(i)$ is the set of firms that do not invest when firm i does not invest.

Proposition 2 ***Investment.*** *For any given $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$, there exist cutoffs $\underline{\phi} > 0$ and $\overline{\phi} \geq \underline{\phi}$ such that the firm does not invest if $\phi \leq \underline{\phi}$ or $\phi > \overline{\phi}$. The upper limit $\overline{\phi}$ satisfies*

(i) $\overline{\phi} = \infty$ if $c_D < c_0$

(ii) $\overline{\phi} < \infty$ if $c_D \geq c_0$

For any $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$, the set of investing firms is

(iii) increasing in $\overline{P}$ and c_0

(iv) decreasing in P_{-i0} and c_D

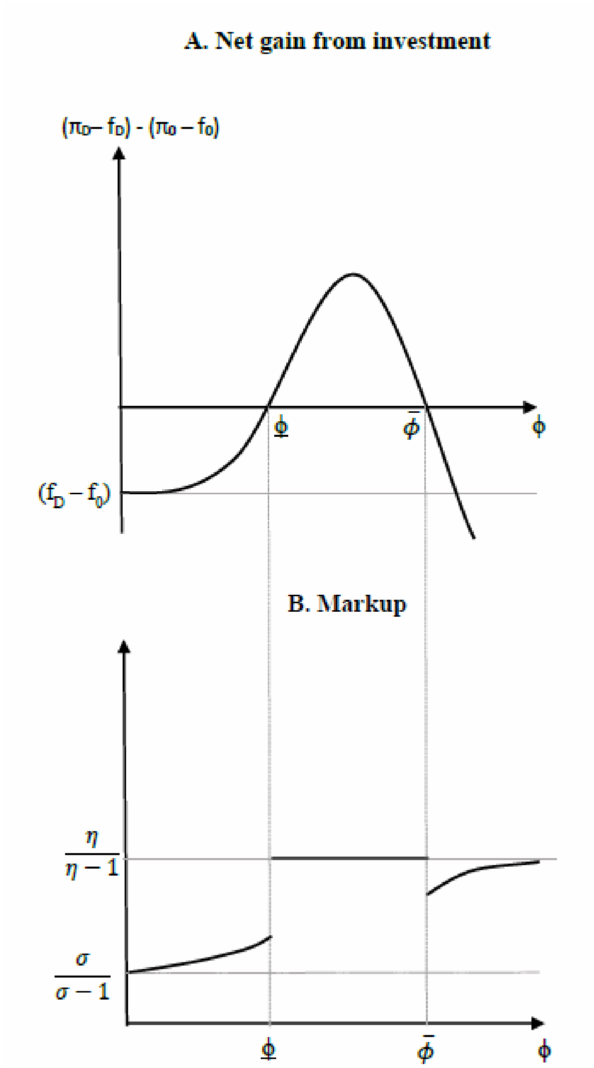
Parts (iii) and (iv) are straightforward applications of the envelope theorem to the profit function (2). The proof of parts (i) and (ii) in Appendix C involves taking limits of the net gains from investing. The Appendix also shows that the set of firms investing is not necessarily convex in productivity ϕ in a given equilibrium, and it finds sufficient conditions for convexity for a given level of competition P_{-i0}.[7]

There are two potential gains from investing in differentiation. First, there is a productivity gain if $c_D < c_0$. This gain is well studied in the literature. Like in Bustos (2011), it is proportional to productivity, and firms with sufficiently high exogenous productivity ϕ invest. Second and more novel, the investment decreases the elasticity of demand. To isolate this gain, assume $c_D > c_0$ so that the productivity gain from investing is not present. Assuming convexity and for a given $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$, figure 1A plots the net gain from investing, $(\pi_D - f_D) - (\pi_0 - f_0)$ as a function of productivity ϕ. (Appendix Figure C1 illustrates the cases $c_D = c_0$ and $c_D < c_0$.)

If the firm is sufficiently unproductive (ϕ is too small) or the market is sufficiently tight ($\overline{P}$ is too small), then the firm does not invest because sales are too small to recoup the fixed cost. If, on the other extreme, the firm is much more productive than its

[7] Sufficient conditions for convexity are (i) that all firms' market share in the non-differentiated nest is less than 0.5, *or* (ii) differentiated goods are sufficiently costly to produce $(c_0/c_D)^{\eta-1} < 0.5$. Arguably, the case where where firms' market shares are less than 0.5 is the empirically relevant one.

Figure 1: Gains from investing and markups when $c_D > c_0$



competitors—relative to P_{-i0}—it faces a low elasticity of demand in nest $\mathcal{O}$ and does not have an incentive to pay a fixed cost to further differentiate its product. In other words, a firm that is close to being a monopolist charges high markups for inferior products. This finding is supported by case studies and anecdotal evidence, surveyed in Holmes and Schmitz (2010).

Figure 1A can also be reinterpreted to capture the effects of competition.[8] When competition is too lax and existing firms are near monopolies, they do not invest. When competition is too tight, firms do not invest because operating profits are too small to recoup the fixed investment. This non-monotonic effect of competition on investment in R&D is reminiscent of Aghion et al. (2005) and Aghion and Griffith (2008). Our model brings these results closer to quantitative models of international trade with CES preferences.[9]

In sum, competition broadly construed has an ambiguous effect on investment. We derive sharper predictions for the impact of *import competition* on firm behavior below.

Assumption 1 *Tariffs are an increase in the price of non-differentiated foreign firms.*

This assumption appears counterintuitive since China is a developing country importing goods mostly from developed countries. But, we interpret product differentiation as an investment to tailor goods to domestic tastes, offer greater customization, and improve non-tradable services offered with products. This interpretation is akin to Holmes and Stevens (2014), who argue that differentiated products require face-to-face interaction with consumers and are more tailored to domestic tastes.[10]

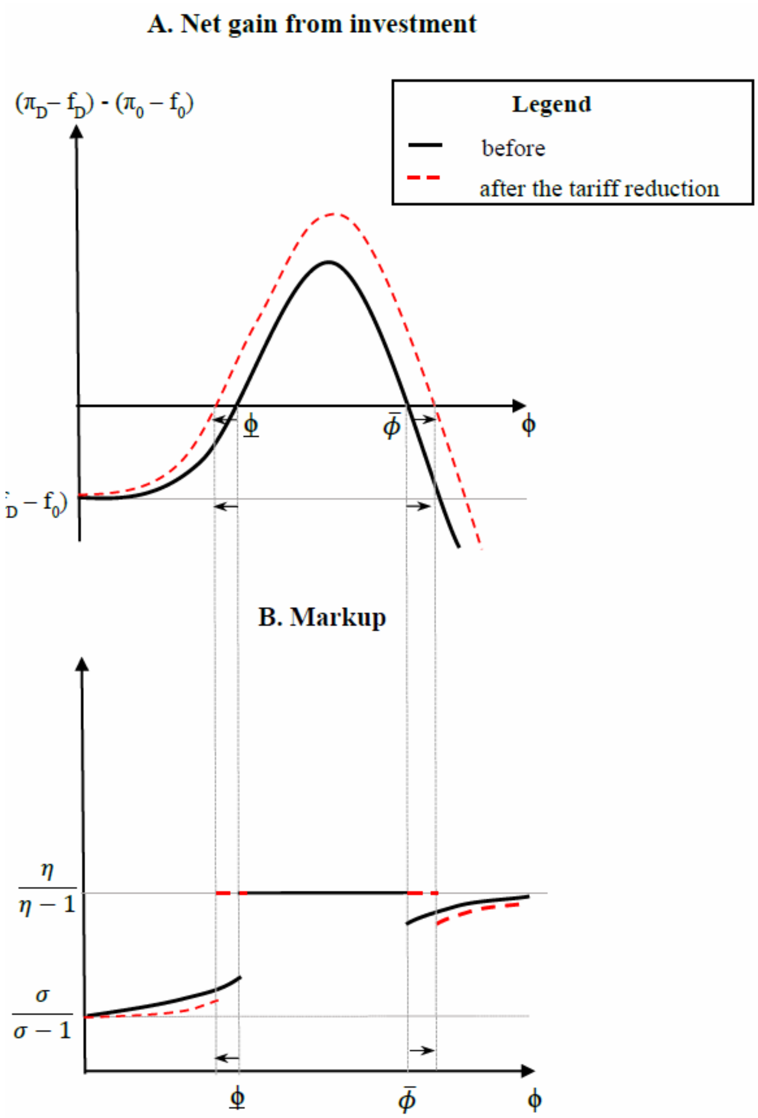
Recalling our earlier examples, the cell phone company Symbio was able to defeat Apple in China by tailoring its products to the Chinese market. Haier, the appliance manufacturer, extended its non-tradable services of delivery, installment, and repairs especially to rural areas. Chery introduced several new, small car models with a much greater variety of optional features and made replacement parts readily available. Again,

[8] Proposition 2 (iii) and (iv) implies that competition, broadly construed as a change in both price indices P_{-i0} and $\overline{P}$, has an ambiguous effect on investment: P_{-i0} increases investment while $\overline{P}$ decreases it. But fixing the ratio $P_{-i0}/\overline{P}$, competition is relaxed if either $\overline{P}$ or ϕ increases—i.e., if the firm becomes more productive relative to its competitors. The change in ϕ is precisely the exercise in Figure 1.

[9] Aghion et al. (2005) and Aghion and Griffith (2008) are difficult to interpret with data because its equilibrium has only one active firm per sector. Other firms affect the equilibrium through their threat of entry, but they are never observed. In Spearot (2013), investment is a non-monotonic function of firm productivity in the cross-section. But different from the new model and Aghion et al, an increase in competition in Spearot always decreases investment.

[10] In Holmes and Stevens (2014), differentiation is exogenous and can only be offered by small firms. In our model, differentiation occurs only in small firms if $f_D < f_0$ and c_D is sufficiently high. In our data, we find evidence of differentiation even among large firms.

Figure 2: Effect of a reduction in tariffs on investment and markups



we interpret the last two changes as a provision of non-tradable services since it is difficult for firms producing cars abroad to offer customized car features, and a wide range of replacement parts.

Proposition 3 ***Import competition.*** *A sufficiently large decrease in import tariffs increases exit. Among surviving firms, it increases investment in differentiation. The markup increases for firms that invest in differentiation, and it decreases for other firms.*

Figure 2 illustrates the effect of the tariff on the gains from investing and on markups in proposition 3 for the firm in Figure 1.[11] The solid black curves are the same as in Figure

[11] Although the proposition holds only for "a sufficiently large decrease in import tariffs", we do not

1. The dashed red line indicates the effects of the tariff reduction. Under assumption 1, it decreases profit π_0 and has no effect on π_D. So, it unambiguously increases the net profit from investing. In Figure 2(b), the markup increases to $\eta/(\eta-1)$ for newly investing firms, and it decreases for firms that remain non-differentiated. So, the effect of output tariffs on Revenue TFP (RTFP) is ambiguous, even though the model unambiguously predicts an increase in investment.

2.1.5 Welfare

The analysis above treats the exogenous set of firms in question as having zero measure, and so consumer welfare is income divided by price index $\overline{P}$, a function of two exogenous parameters. We can, nonetheless, conduct welfare analysis by assuming either that (i) the firms above are not zero measure but they are small enough to take the price index $\overline{P}$ as exogenous, or (ii) the sectors not modeled arise from a continuum of finite sets of firms symmetric to the ones described above. In both interpretations, the positive predictions of firm behavior above remain unchanged, and yet the analysis of the welfare effect of labor allocations is meaningful. Appendix C has all the mathematical proofs together with a more detailed discussion of the results.

First, we fix discrete choices of exit and investment, and show that markup dispersion leads to labor missallocation. After firms' discrete choices are made, *constrained planner 1* can unexpectedly choose the allocations of labor.

Lemma 4 ***Labor misallocation.*** *For any two non-differentiated firms, constrained planner 1 allocates relatively more labor to the more productive firm compared to the market. Constrained planner 1 also allocates more labor to differentiated varieties relative to non-differentiated varieties.*

The proof is a small extension of Edmond et al. (2015). To see it, consider two non-differentiated varieties i and i' with $\phi_i > \phi_{i'}$. From pricing equation (3), markup $\mu_i > \mu_{i'}$.

view this condition as restrictive since it merely requires competition to tighten for all domestic firms. It is easily met in our empirical application given the massive increase in imports following China's accession to the WTO. A small decrease in non-differentiated foreign prices does not necessarily decrease P_{-i0} for all domestic firms i because it may lead some of firm i's domestic competitors to leave nest $\mathcal{O}$ by investing or not producing. But trivially, if P_{0F} decreases to less than the original P_{-i0}, it decreases P_{-i0}.

To see why the statement of the proposition breaks down for small decreases in P_{0F}, consider an example with two firms. Before the liberalization, the more productive firm invests because it cannot deter the entry of the second firm into nest $\mathcal{O}$ if it does not invest. As foreign price P_{0F} decreases with the trade liberalization, the first firm may choose not to invest because it deters the entry of the second firm into nest $\mathcal{O}$. Then, firm 1 divests with the trade liberalization. In this example, however, the decrease in P_{0F} is not sufficiently large. Price index $P_{-1,0}$ increases firm 2 leaves nest $\mathcal{O}$, either by not producing or investing. This example highlights that strategic interactions between large firms may lead to unexpected, often counterintuitive results—as in oligopoly games in Tirole (1988).

Simple CES maximization implies the following relationship between the planner's and the market's labor allocations:

$$\frac{\text{labor}_i^{\text{planner}}}{\text{labor}_{i'}^{\text{planner}}} = \left(\frac{\phi_i}{\phi_{i'}}\right)^{\sigma} > \left(\frac{\phi_i/\mu_i}{\phi_{i'}/\mu_{i'}}\right)^{\sigma} = \frac{\text{labor}_i^{\text{market}}}{\text{labor}_{i'}^{\text{market}}}.$$

In words, the planner allocates labor according to costs, and in the market equilibrium, the consumer allocates it according to prices. So, the consumer spends relatively less on varieties with higher markups. These varieties are differentiated and more productive varieties within the non-differentiated nest, as stated in Lemma 4.

We now turn to the more novel analysis of the discrete choices of exiting and investing. To analyze planner's problem, we must put some structure into the gains from reallocating labor to and from sectors not modeled. Denote with C the aggregate marginal cost of labor in the economy. For example, if marginal cost is constant in other sectors, then $C = L/Q$ where L is labor allocated for production (net of fixed costs) and Q is the standard CES aggregate quantity. Define the average markup in the economy as $\overline{\mu} = \overline{P}/C$, price over marginal cost. We uphold the following assumption:

Assumption 2 *The market equilibrium satisfies $\overline{\mu} < \eta/(\eta - 1)$ and $\overline{\mu} \geq \epsilon_{0i}/(\epsilon_{0i} - 1)$ for all i in the non-differentiated nest $\mathcal{O}$.*

In the market equilibrium, the markup of differentiated firms is always higher than the markup of non-differentiated firms, $\eta/(\eta-1) > \epsilon_{0i}/(\epsilon_{0i}-1)$. If all sectors are modeled symmetrically to the one above, then Assumption 2 will be satisfied when there is a sufficient number of differentiated firms so that $\overline{\mu}$ is close to $\eta/(\eta-1)$, and market shares in the non-differentiated nest are sufficiently spread across firms so that no firm holds an almost monopoly and has markups close to $\eta/(\eta-1)$.

Define the *constrained planner 2* as a planner who makes the discrete choices of exit and investment for all firms, but cannot change the allocation of labor once discrete choices are made. Firms are free to set prices and the market clears. The *unconstrained planner* makes discrete choices and allocates labor across firms.

Proposition 5 ***Distortions on Investment and Exit.*** *Relative to the constrained planner 2 and the unconstrained planner, the market features too much entry of unproductive, non-differentiated varieties in $\mathcal{O}$ and too little investment in differentiation.*

Proposition 5 is at a first sight counterintuitive because the planner prefers varieties with higher markups, but a sketch of the proof shows that higher markups reflect preferences and that there is business stealing among non-differentiated varieties.

For constrained planner 2, the utility loss from eliminating a variety is given by changing the variety's price to infinity in the consumer's indirect utility function, while the gain stems from saving the fixed cost. The proof uses Roy's identity, which relates the demand function to the consumer's indirect utility function. As we take the price of a differentiated variety to infinity, the consumer always values it with an elasticity η. In contrast, as we take the price of a non-differentiated variety to infinity, the elasticity of demand increases from ϵ to σ. That is, although the non-differentiated firm charges a markup $\epsilon/(\epsilon-1)$ for all its units sold, the consumer substitutes it for other non-differentiated varieties with an elasticity closer to σ as the variety is eliminated. So, the firm's profit is larger than the social benefit.[12] Once the proposition is established for the constrained planner 2, lemma 4 implies that it also holds for the unconstrained planner.

According to Proposition 3, import competition pushes the least-productive firms to exit and surviving firms to invest in differentiation. Assuming that firms close to the exit threshold are non-differentiated, Proposition 5 establishes that these trade-induced changes in discrete choices improve welfare even when the planner cannot change labor allocations. So, investment in differentiation is a new gain from trade:

Corollary 6 *Compared to a scenario where firms are forced not to change their discrete choices, the exit of the least-productive, non-differentiated firms and the increase in investment induced by import competition always improves welfare.*

2.2 Upstream (supplying) enterprises

In this section we focus on an important extension to the model: allowing for investment in product differentiation for upstream suppliers. This is a critical extension because it serves to make sense of the empirical results which follow and show magnification of RTFP for upstream suppliers as a result of trade reforms. However, we also developed other extensions to the model, including (i) allowing the fixed costs of investing to depend on the number of nests already created, and (ii) allowing for imitation and for the elasticity of demand σ to vary across nests. (iii) We revisit all results above in a general equilibrium model with two symmetric countries, and (iv) derive gravity-type expressions in a variant of the model with asymmetric countries, where ex ante symmetric firms within countries produce varieties in heterogeneous nests. Like in the model above, international trade

[12] The proof departs from the original Dixit and Stiglitz (1977) because as the firm's quantities change, its elasticity of demand also changes. Eliminating a large firm from the non-differentiated nest has a lower welfare cost than eliminating a continuum of varieties in Dixit and Stiglitz (1977).

reallocates production toward nests with a lower elasticity of demand (differentiated nests) and with a higher local demand. These extensions appear in Appendix E.

We add an upstream sector to the model. As before, to focus on the effect of import competition, we assume that input suppliers do not export in the sector modeled. Whenever it is important to distinguish upstream from downstream variables, we use subscript M (for "materials"). The propositions above all hold in the extended model.

Upstream firms are modeled symmetrically to downstream firms. There is an exogenous and finite set of input suppliers. Each firm has monopoly rights over a unique input variety. It chooses to exit, produce a non-differentiated variety, or produce a differentiated variety. The fixed cost of production is f_{0M} if the firm does not invest in differentiation, and $f_{DM} > f_{0M}$ if it invests. A key assumption, discussed further in Section 2.3, is that differentiated downstream varieties cannot be made with non-differentiated inputs.

2.2.1 Non-differentiated upstream firms

The input cost of non-differentiated final goods is

$$c_0 = \left[(P_{0M})^{1-\eta_M} + (P_M)^{1-\eta_M}\right]^{\frac{1}{1-\eta_M}} \tag{6}$$

$$\text{where} \quad P_{0M} = \left[\sum_{i\in\mathcal{O}_M} (p_i)^{1-\sigma_M}\right]^{\frac{1}{1-\sigma_M}},$$

$\mathcal{O}_M$ is the set of non-differentiated upstream varieties, p_i is the price of variety i, P_{0M} is the price index of non-differentiated inputs, and P_M is the price index of all other inputs—potentially including labor, capital and materials from other upstream sectors. Assume $\sigma_M > \eta_M > 1$.

Normalize to one the input cost of non-differentiated upstream firms so that an upstream firm with productivity ϕ_M has marginal cost $1/\phi_M$. Given equation (6), the profit of this upstream firm is

$$\pi_0^M = \max_p X_{0M} c_0^{\eta_M - 1} (P_{0M})^{\sigma_M - \eta_M} p^{-\sigma_M} (p - 1/\phi_M) \tag{7}$$

where p is the price and X_{0M} is spending on materials by domestic, downstream non-differentiated firms. As in the downstream sector, we take P_M and c_0 as exogenous, while price index P_{0M} and set $\mathcal{O}_M$ are endogenous. Since c_0 is exogenous, the firm also takes X_{0M} as given. (In Appendix D, we study a model where c_0 is endogenous and input suppliers internalize the effect of their prices on sales downstream and on X_{0M}.[13])

Taking the first order conditions, the optimal markup of the upstream firm is $\epsilon_M/(\epsilon_M - 1)$ where ϵ_M is the endogenous elasticity of demand:

$$\epsilon_M = \sigma_M(1 - s_M) + \eta_M s_M \tag{8}$$

$s_M = (p/P_{0M})^{1-\sigma}$ is the market share of the firm in nest $\mathcal{O}_M$. Analogous to the downstream firm's pricing decision in equation (3), the endogenous elasticity of demand is a weighted average between the within-nest elasticity σ_M and the across-nest elasticity η_M.

2.2.2 Differentiated upstream firms

As in the downstream sector, we simplify the problem of differentiated firms by assuming that there is a continuum and exogenous set of differentiated varieties. The input cost to produce differentiated final goods c_D is exogenous. An upstream differentiated firm with productivity ϕ_M charges markup $\frac{\eta_M}{\eta_M - 1}$ over marginal cost and gets profits

$$\pi_{DM} = (\phi_M)^{\eta_M - 1} X_{DM}. \tag{9}$$

Parameter X_{DM} captures the size and tightness of the market, input costs, and potential productivity changes from the investment in differentiation.

2.2.3 Equilibrium with intermediate inputs

Foreign prices and productivity of all firms are exogenous and known. Timing is as follows. (i) In order of productivity, all upstream firms make their discrete choices. (ii) In order of productivity, all downstream firms make their discrete choices. (iii) All firms, upstream and downstream, simultaneously set prices. (iv) Markets clear.

The first-mover advantage of more productive firms implies that there exist exit cutoffs, $\tilde{\phi}$ and $\tilde{\phi}_M$ for downstream and upstream firms, as in proposition 1. Discrete choices are set before prices so that firms cannot commit on prices to manipulate discrete choices. The ordering of (i) and (ii) is not important. The simultaneous setting of prices implies that a firm takes other firms' prices as exogenous. That is, it best responds to other firms' equilibrium prices, and the pricing decisions of downstream and upstream firms above are

[13]The main conclusions below hold, though pricing decisions of upstream firms are significantly complicated. Non-differentiated upstream firms may decrease their markups in response to import competition downstream. We show that this effect is generally small because it is proportional to the ratio of the upstream firm sales relative to the total cost of domestic non-differentiated downstream firms, including labor, and materials from other sectors.

correctly specified.

2.2.4 Import Competition for Downstream and Upstream Firms

Proposition 7 *A sufficiently large decrease in import tariffs increases the exit of upstream firms. Among surviving upstream firms, it increases investment in differentiation and markups.*

Proposition 7 is analogous to Proposition 3 for downstream firms. The direction of exit and investment is the same, and firms that invest always increase their markups. Here, a firm that remains non-differentiated also increases its markup because its market share increases as other non-differentiated input suppliers exit or invest. This pricing result is the opposite of Proposition 3.

A precise quantitative comparison between up and downstream firms is infeasible because these sectors may differ in various respects—e.g., elasticities of substitution, fixed costs, distributions of technologies. Still, to get a sense of magnitude, we apply the Envelope Theorem to profits in equations (4) and (7). The elasticity of profits in the non-differentiated nest with respect to to the price index of foreign downstream firms, P_{0F}, is the same for upstream and downstream firms:[14]

$$\frac{P_{0F}}{\pi_0}\frac{d\pi_0}{dP_{0F}} = \frac{P_{0F}}{\pi_0^M}\frac{d\pi_0^M}{dP_{0F}} = \sigma - \eta. \tag{10}$$

These derivatives ignore general equilibrium effects that, with large firms, may lead to discrete jumps in profits π_0 and π_0^M. But ceteris paribus they suggest that incentives to invest in differentiation are not smaller for upstream firms than for downstream firms. The key assumption is that non-differentiated upstream firms sell only to non-differentiated downstream firms. Then, import competition decreases sales in the same proportion for non-differentiated upstream and downstream firms.

To summarize, import competition downstream decreases the market for domestic non-differentiated firms. This market size effect increases exit and investment, and it has the same magnitude for non-differentiated downstream and upstream firms. Markups, in turn, are determined by a firm's market share within its nest, as in Atkeson and Burstein (2008). While import competition decreases the market share of downstream firms, it does not directly change the market share of upstream firms.

[14] To take the derivative of $\frac{d\pi_0^M}{dP_{0F}}$, one must expand the term X_{0M} of domestic non-differentiated firms' spending on materials.

This heterogeneous effect of import competition on markups may explain the empirical findings of Section 3. We will show that tariff reductions increase TFP of both import competing firms and their suppliers. We will also document that the impact is larger for suppliers. In the model, tariff reductions lead both sets of firms to invest in differentiation, but markups only fall for non-differentiated downstream firms. Since investment and markups go in opposing directions, the model predicts that the coefficient on output tariffs should be smaller in magnitude than the coefficient on downstream tariffs. More broadly, this result suggests that measured productivity is a faulty proxy for investment in differentiation. Consequently, we propose more direct proxies for the investment to study firm responses to trade reform.

2.3 Measuring Investment in Differentiation

Assumption 3 *Investment in differentiation is associated with:*

(i) the introduction of new goods,

(ii) a higher probability of switching sectors,

(iii) an increase in skill intensity.

Parts (i) and (ii) are almost tautological. In the model, investment in differentiation changes the firm's variety, and differentiated varieties compete more directly with other sectors. In the data, investment in product differentiation may include changes in the physical attributes of products, as well as changes in product appeal through advertising or added customer service. Part (iii) holds if differentiated goods have on average higher quality since there is ample evidence that higher-quality goods are skill intensive.[15] It may also hold if, as in the examples below, new products lead to restructuring of management or production processes, and implementing these changes requires skilled labor. Corollary 8 summarizes propositions 3 and 7 highlighting the links to the data that we'll test below.

Corollary 8 *A sufficiently large decrease in tariffs has the following effects on* ***import-competing firms***

(i) it increases exit

(ii) it decreases sales of non-differentiated firms

[15] See Bernard et al. (2007), Verhoogen (2008), Fieler et al. (2018).

(iii) it increases the introduction of new goods

(iv) it increases the probability of switching sectors

(v) it increases skill intensity

(vi) it increases the markup of firms that invest in differentiation

(vii) it decreases the markup of non-differentiated firms

Effects (i) through (vi) hold also for ***input suppliers****. Effect (vii) is reversed for input suppliers.*

Consider again the automobile company Chery. Its strategy to escape import competition consisted of introducing new car models, especially small, fuel-efficient cars; increasing the customization of car features, and making replacement parts readily available. The design and frequent launches of new models require skilled workers.[16] The increase in product scope is viable with the implementation of just-in-time inventory controls and investment in modern, flexible equipment. Modern equipment is amenable to production in small batches and improves the quality of output, which is in Chery's own interest given its commitment to make car parts readily available.

To be effective, all these improvements in Chery—production of car models in small batches, higher-quality parts, and just-in-time inventory controls—have to be matched by mirror improvements in input suppliers. Like other auto-makers, Chery also designs new car parts in partnership with its suppliers.

In sum, even though the Chinese consumers are relatively poor, escaping competition involves broad quality upgrades in import-competing firms *and in their input suppliers*. This broad interpretation of the investment helps us justify the model's key assumption that producing differentiated varieties requires differentiated inputs, from which all predictions of Corollary 8 on input suppliers stem. So, although we observe only the few proxies for the investment listed in Assumption 3, studying empirically the effect of tariffs on import-competing firms' input suppliers is new and allows us to test a much larger set of predictions of the model.

3 Empirics

We begin by reporting the relationship between three tariff measures and the most standard measure of firm performance employed in the empirical trade literature, total factor

[16]This assertion holds even if Chery's innovation were imitated from abroad. In fact, Chery was sued for violations of intellectual property rights by GM.

productivity (TFP). We primarily examine the relationship between tariffs and revenue total factor productivity (RTFP), where firm level revenues are deflated by sector-level price deflators. One implication is that when individual firm-level markups deviate from sector-level markups, this is reflected in RTFP as either an increase (when markups increase) or a decline (when markups fall). Since our theory incorporates changes in a markup component as well as in a product differentiation and investment component, RTFP is the appropriate measure to capture both these consequences of trade reform.[17]

To measure investment in product differentiation more directly, rather than indirectly through a variety of TFP measures, we draw on the theory to explore the consequences for product switching and new product introductions. We describe the data in section 3.1, the empirical procedure in section 3.1.2, and the results in section 3.1.3. We then move on to explore the underlying mechanisms for the TFP results, and conclude our empirical work with extensions and robustness tests.

3.1 The Impact of Tariffs on TFP

3.1.1 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. These data have been extensively used in a number of papers, and for more details, we refer the reader to Du et al. (2012), Aghion et al. (2015), and Brandt et al. (2017).

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

[17]The division of RTFP into prices and quantities generally applies to sectors with homogenous goods, as argued in Foster et al. (2008). See also Harrison (1994) and De Loecker (2007) for discussions on measured productivity the context of trade reforms. The model has no predictions on Quantity TFP because, like in Melitz (2003), firm productivity may capture both efficiency and quality.

revenue, and export sales. We classify firms as domestic or foreign-owned. Domestic firms are those with zero foreign capital in their total assets. About 77.5 percent of firms are classified as domestic and 22.5 percent as foreign-owned. We restrict the sample of domestic firms to firms with zero or a minority state ownership. The final sample has 991,440 observations. The Chinese Input-Output table (2002) has 71 sectors, while the firm-level survey has 4-digit industry classifications. To construct downstream tariffs below we aggregate the 4-digit classification up to these 71 sectors. For example, the furniture industry 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).

3.1.2 Measuring Productivity and Tariffs

Total Factor Productivity (TFP). We measure TFP for each firm and year using a standard two-stage procedure developed by Olley and Pakes (1996). However, we also present results using OLS and firm fixed effects to derive TFP as well as the more recent innovations proposed by Ackerberg et al. (2015). For the Olley-Pakes (OP) estimation, in the first stage we estimate a three-input gross-output production function for each 2-digit sector. We use the estimated factor output elasticities for labor, capital, and materials to construct measures of total factor productivity 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:

$$\ln Y_{ijt} = \alpha_0 + \alpha_L \ln L_{ijt} + \alpha_M \ln M_{ijt} + \alpha_K \ln K_{ijt} + \mu_{ijt} \tag{11}$$

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, detailed below. The purpose of the first-stage is to get unbiased estimates of the factor-output elasticities.

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

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

$$\ln TFP_{ijt} = \beta_1 \ln \text{Output\_Tariff}_{jt} + \beta_2 \ln \text{Upstream\_Tariff}_{jt} + \beta_3 \ln \text{Downstream\_Tariff}_{jt} + S_{jt} + \Sigma\alpha_i + \Sigma\alpha_t + \varepsilon \quad (12)$$

where $\ln TFP_{ijt}$ is 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 (11) above. In equation (12) α_i are firm fixed effects, α_t are time fixed effects, and S_{jt} are firm- and time-varying control variables described below.

Tariffs. We construct three tariff measures for each firm and year. Consider a firm in sector j. First, a decrease in sector-j tariffs increases import competition for the firm. We refer to these own-sector tariffs as output tariffs. Second, the tariffs on the sectors that provide inputs to sector j affect the firm's costs. We refer to these tariffs as upstream tariffs. The literature often refers to them as input tariffs, and we change the nomenclature to make it symmetric to the novel concept of downstream tariffs. Third, if sector j provides inputs to a sector whose tariffs are cut, the firm may be impacted. We refer to these tariffs as downstream tariffs. The first two types of tariffs—output and upstream tariffs—have been extensively analyzed in the trade literature, while the effect of downstream tariffs has, to our knowledge, only been documented in the context of foreign direct investment (e.g., Javorcik (2004) and Blalock and Gertler (2008)).

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

While we use Brandt et al. (2017)'s measures of final and upstream tariffs, we construct our own downstream 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 that sectoral classifications differ across data sources. We end up with 71 sectors that comprise a wide range of economic activities, such as ship-building, electronic computers, tobacco products, motor vehicles, and parts and accessories for motor vehicles. The aggregation of tariffs to this 71-sectoral classification uses the output in 2003 as weights.

To construct upstream tariffs, Brandt et al. (2017) use China's Input-Output table

(2002) and follow the procedures suggested by Amiti and Konings (2007). The upstream tariffs are 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 upstream tariff for that chocolate industry is equal to 60 percent of the sugar tariff plus 40 percent of the cocoa tariff.

More specifically, the upstream tariff in Amiti and Konings (2007) and Brandt et al. (2017) is calculated as:

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

where δ_{jm} is the share of sector m provided as an input to sector j. Our downstream tariff measure is calculated as:

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

where α_{jk} is the share of sector j's production supplied to downstream sector k. The values of α_{jk} and δ_{jm} are both taken from the 2002 input-output table. Downstream tariffs will be highest in those sectors j where the downstream users in sector k face high tariffs and demand a large share of sector j's output. This concept of a "downstream tariff" is a new one. It allows us to analyze in the data the effect of import competition downstream on input suppliers' outcomes.

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

Following the literature, we use initial tariffs as instruments.[18] Output tariffs, upstream tariffs, and downstream tariffs are instrumented using the initial period value for these tariffs at the firm level interacted with a dummy variable equal to one after China entered the WTO. We cannot use the initial tariffs alone as an instrument because our

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

regressions have firm fixed effects. If the firm did not exist in 1998, we use the initial mean tariff in the firm's sector.

Additional control variables. Control variables capture exposure to foreign investment at the sector level, and policy and ownership variables. Following Javorcik (2004), we define three sector-level FDI variables. Horizontal_{jt} captures foreign presence in sector j at time t, and it is defined as foreign equity participation averaged over all firms in the sector, weighted by each firm's share in sectoral output. $\text{Downstream\_FDI}_{jt}$ is a measure of foreign participation in the sectors that are supplied by sector j, i.e., in sectors downstream from j. Upstream_FDI_{jt} is a measure of foreign participation in sectors upstream from j. We refer the reader to Javorcik (2004) for details on the construction of these FDI variables. Industrial policy is captured through zero-one dummy variables indicating whether the firm received subsidies (index_subsidies), whether the firm received a tax holiday (index_tax), and whether the firm paid below median interest rates on loans (index_interest). Finally, we control for the share of state ownership in the sector of the firm. Compared to other studies, our control variables are very detailed, but level of aggregation is high—Amiti and Konings (2007), for instance, use 4-digit measures of protection for Indonesia, while we can only use 3-digit measures for tariffs and FDI.

3.1.3 Results on Tariffs and TFP

Table 1 shows the results from regression (12) of TFP on tariffs. TFP is measured using either the OP approach or OLS with fixed effects in the first stage. All regressions have fixed effects for firm, sector, and year. The sample includes only establishments without foreign ownership or significant public ownership. (These firms are added to Table 2.)

The key results are in the first three rows: the coefficients on output tariffs, downstream tariffs, and upstream tariffs. The negative coefficients in all specifications indicate that reductions in these three tariff measures are associated with increases in TFP. Columns (1) and (2) report the coefficients from the OLS regressions. The instrumental variable (IV) estimates are reported in Columns (3) and (4). The coefficient on the WTO dummy interacted with initial tariff levels in the first stage (not reported) 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 output tariffs in the OLS and OP specifications are both significant and negative. These coefficient estimates of -0.0478 and -0.0459 indicate that a ten percent reduction in tariffs raises TFP by 0.3 to 0.5 percent. Columns (5) and (6) repeat the estimation but exclude exporting enterprises. The coefficients above increase (in absolute value) to -0.0592 and

Table 1: Basic Regressions of Productivity on Tariffs

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

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
	OP	FE	OP	FE	OP	FE
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0312***	-0.0331***	-0.0478***	-0.0459***	-0.0592***	-0.0566***
	(0.0082)	(0.0087)	(0.0109)	(0.0112)	(0.0110)	(0.0112)
downstream_tariff	-0.0154	-0.0168	-0.173***	-0.169***	-0.426***	-0.451***
	(0.0308)	(0.0366)	(0.0372)	(0.0373)	(0.0474)	(0.0476)
upstream_tariff	-0.130***	-0.140**	-0.350***	-0.461***	-0.217***	-0.308***
	(0.0445)	(0.0528)	(0.0610)	(0.0620)	(0.0638)	(0.0647)
index_subsidy	0.0108***	0.0130***	0.0103***	0.0123***	0.00747***	0.00879***
	(0.0018)	(0.0017)	(0.0011)	(0.0011)	(0.0014)	(0.0014)
index_tax	0.0216***	0.0220***	0.0214***	0.0217***	0.0211***	0.0216***
	(0.0009)	(0.0009)	(0.0007)	(0.0007)	(0.0008)	(0.0008)
index_interest	-0.0121***	-0.0133***	-0.0120***	-0.0132***	-0.0134***	-0.0146***
	(0.0012)	(0.0011)	(0.0008)	(0.0008)	(0.0009)	(0.0009)
exportshare_sector	0.12	0.166	0.388***	0.479***	0.479***	0.581***
	(0.142)	(0.145)	(0.030)	(0.031)	(0.038)	(0.039)
State_share	-0.00154	-0.000965	-0.00194	-0.00148	-0.000568	0.000428
	(0.0037)	(0.0037)	(0.0039)	(0.0039)	(0.0044)	(0.0044)
Horizontal FDI	0.151	0.212	0.144***	0.198***	0.236***	0.299***
	(0.180)	(0.200)	(0.022)	(0.022)	(0.027)	(0.028)
Downstream FDI	1.074	0.982	1.635***	1.559***	2.266***	2.237***
	(0.783)	(0.904)	(0.148)	(0.149)	(0.187)	(0.189)
Upstream FDI	0.085	0.0911	0.150***	0.176***	0.036	0.0637
	(0.404)	(0.409)	(0.036)	(0.037)	(0.043)	(0.043)
Observations	982,142	982,142	982,142	982,142	777,739	777,739

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

-0.0566, respectively, suggesting that import competition has a positive effect on firm TFP beyond firms' participation in global value chains and export markets.

The coefficients on downstream tariffs are much larger than the coefficients on output tariffs in all IV specifications. For example, with the subsample of non-exporting firms in Columns (5) and (6), the coefficient on downstream tariffs is -0.426 when tariffs are measured à la Olley-Pakes and -0.451 when they are measured with OLS, about eight times larger than the coefficients on output tariffs. These differences in magnitudes are robust to numerous robustness checks in Section 3.3. Documenting the negative impact of these downstream tariffs on productivity and other firm outcomes is the primary empirical contribution of this paper.

Consistent with the literature, the coefficients on upstream tariffs suggest that access to foreign inputs increases TFP. The coefficients on the control variables are also plausible and reassuring. Subsidies and tax holidays are associated with higher TFP at the firm level, while subsidized interest rates are associated with lower TFP. The coefficients on vertical linkages from foreign ownership are generally positive and significant, while the coefficients on horizontal linkages are insignificant in the OLS specifications but positive and significant in the IV specifications.

For comparative purposes, Table 2 follows closely the specification employed by Loren Brandt, Johannes Van Biesebroeck, Luhang Wang, and Yifan Zhang (2017). Table 2 uses lagged log of tariffs and a sample that includes both public sector enterprises and foreign firms. Also similar to Brandt et al. (2017), Tables 1 and 2 include 2-digit sector dummies to diffuse the concern that TFP measures may not be comparable across sectors. Appendix Table A.2 shows that our results are robust to removing 2-digit sector dummies. While our main empirical findings pertain to downstream tariffs, it is reassuring that our results on output tariffs are comparable in magnitudes to Brandt et al. (2017).

In sum, Tables 1 and 2 show that a reduction in all three measures of tariffs is associated with increases in TFP. The coefficient on downstream tariffs is significantly larger than the coefficient on output tariffs in all IV specifications. The model explains this difference in magnitude as follows: final goods producers and input suppliers both invest in differentiation, but final-goods producers experience larger markup reductions since they are directly faced with import competition.

A large class of trade models explains the relationship between productivity and trade through economies of scale, e.g., Bustos (2011), Caliendo and Rossi-Hansberg (2012), Helpman et al. (2017). In these models, an increase in import competition decreases sales and the incentives for firms to invest. These models are thus inconsistent with Tables 1

Table 2: Regressions including public-sector enterprises and firms with minority foreign ownership and lagged tariffs

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

	All Enterprises				Only Non-Exporters	
	OP	FE	OP	FE	OP	OP
	OLS	OLS	IV	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0285***	-0.0297***	-0.0421***	-0.0372***	-0.0329***	-0.0520***
	(0.0067)	(0.0070)	(0.0108)	(0.0111)	(0.0078)	(0.0114)
downstream_tariff	-0.0245*	-0.0254*	-0.117**	-0.123**	-0.0319**	-0.573***
	(0.0135)	(0.0146)	(0.0515)	(0.0520)	(0.0151)	(0.0739)
upstream_tariff	-0.0195	-0.019	-0.737***	-0.814***	-0.00961	-0.413***
	(0.0175)	(0.0188)	(0.0690)	(0.0702)	(0.0181)	(0.0710)
Observations	821,970	821,970	821,970	821,970	619,448	619,448

Specifications are the same as table 1, except that this table uses lagged tariffs and includes public-sector enterprises and firms with minority foreign ownership. The number of observations decreases with the use of lagged tariffs and increases due to the larger set of firms. We report here only the coefficients on the variables of interest. Appendix Table A3 reports the coefficients on all control variables. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

and 2, which show that tariff reductions in China increased firm TFP.[19]

3.2 Mechanisms

This section tests the predictions of Corollary 8 for new goods and skill intensity. The rest of the paper follows the empirical specification in equation (12):

$$\begin{aligned} y_{ijt} =& \beta_1 \ln \text{Output\_Tariff}_{jt} + \beta_2 \ln \text{Upstream\_Tariff}_{jt} + \beta_3 \ln \text{Downstream\_Tariff}_{jt} \\ & + S_{jt} + \Sigma\alpha_i + \Sigma\alpha_t + \varepsilon \end{aligned} \tag{13}$$

where y_{ijt} is the outcome of interest for firm i, in sector j at time t, and α_i and α_t are firm and time fixed effects respectively. Control variables S_{jt} and the instrumental variables for tariffs are described in Section 3.1.2. Tariff measures refer to tariffs imposed by China on its imports. The tariff on the firm's own sector is the Output_Tariff$_{jt}$, the tariff on sectors upstream from j is the Upstream_Tariff$_{jt}$, and the tariff on sectors downstream from j is the Downstream_Tariff$_{jt}$. The predictions of Corollary 8 on import-competing firms refer to coefficients on output tariffs, and the predictions on input suppliers refer to coefficients on downstream tariffs. The roman numerals in parentheses refer to the corollary.

New goods (iii). Tariff reductions in the model lead import-competing firms and their suppliers to introduce new goods. Table 3 tests these predictions using two measures of the introduction of new goods. First is the share of new products in total sales, as reported at the establishment level. Second, we use a dummy variable equal to one if the establishment introduces a new product in a particular year.

The coefficients of interest are primarily the first three rows of Table 3. Focusing on the IV specifications, column (2) indicates that a one standard deviation reduction in log output tariffs (around .5) would be associated with an increase in new products of 0.8 percentage points in total sales (multiplied by -0.0164). The coefficient on downstream tariffs is also significant and negative, and it is twice as large. A one standard deviation reduction in downstream tariffs is associated with an increase in the share of new products in revenues of 1.5 percentage points.

Columns (3) and (4) of Table 3 repeat the estimation but instead use a zero-one dummy as an indicator of whether the enterprise introduced a new product. The results indicate

[19] Appendix B reports results relating sales to TFP and tariffs. As expected, sales are positively associated with TFP in the cross section, and over time, tariff cuts generally decrease sales. This finding that tariffs move sales and TFP in opposite directions is inconsistent with the economies-of-scale hypothesis.

that a reduction on both output and downstream tariffs are associated with a significant increase in the introduction of new products. The results are robust to restricting the sample only to non-exporting enterprises, as reported in the last four columns of Table 3. In all, Table 3 provides evidence that import-competing firms and their input suppliers innovate in response to tariff reductions.[20]

Skill Intensity (v). The model predicts that tariff reductions increase the skill intensity of import-competing firms and of their input suppliers. Although we do not observe firms' skill intensity in every year in our data, the 2004 survey asked firms for details on the composition of their work force. We use this 2004 cross-section to measure sectoral skill intensity and then verify that tariff cuts prompted firms to switch to skill-intensive sectors.

We define skilled workers as those who have completed a senior high degree, or a three- or four-year college degree.[21] We calculate the share of skilled workers in each firm's labor force in 2004 and then aggregate this firm level information to the sector level to construct a ranking of sectors in increasing order of skill intensity. There are 450 sectors in the data. The least skill intensive sector was the production of packaging and bags, while the most skill intensive sector was a subsector in aircraft manufacturing. We merge these sectoral ranks with our panel of firms, from 1998 to 2007.

Table 4 presents the results from regression (13) where the dependent variable is sectoral rank (with highest indicating most skill-intensive). The first two columns report coefficients for all firms. 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. Since all specifications include firm fixed effects, the identification stems from firms switching sectors. Approximately 15 percent of establishments in the sample change sectoral affiliation over the 1998 through 2007 period.

As predicted by the model, the coefficient on output tariffs is consistently negative and significant, with point estimates ranging from -13 to -149. The results indicate that a decline in output 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) is associated with a movement up the rank that ranges between 7 and 75 sectors.

[20]The Chinese government has many programs to reimburse input tariffs, and so our upstream tariff measure may not capture the actual trade barriers faced by firms importing inputs. This point may explain the unexpected sign of the coefficient on upstream tariffs in Table 3 and in many of the tables below.

[21]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.

Table 3: Introduction of New Goods, Instrumental Variable Estimates

	All Enterprises excluding SOE's and multinationals				**Only Non-Exporting Enterprises**	
dependent variable →	new product share	new product share	0-1 dummy for introducing a new product	0-1 dummy for introducing a new product	0-1 dummy for introducing a new product	new product share
	OLS	IV	OLS	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.000475	-0.0164***	-0.000554	-0.0413***	-0.0309***	-0.0107***
	(0.0021)	(0.0044)	(0.0047)	(0.0091)	(0.0077)	(0.0038)
downstream_tariff	-0.00369	-0.0302***	0.00824	-0.0606***	-0.0547***	-0.0359***
	(0.0033)	(0.0106)	(0.0105)	(0.0209)	(0.0212)	(0.0110)
upstream_tariff	0.0032	0.0349**	-0.000129	0.110***	0.100***	0.0419***
	(0.0045)	(0.0161)	(0.0110)	(0.0325)	(0.0286)	(0.0146)
index_subsidy	0.00653***	0.00657***	0.0175***	0.0177***	0.0118***	0.00455***
	(0.0012)	(0.0007)	(0.0025)	(0.0013)	(0.0013)	(0.0007)
index_tax	-0.000638*	-0.000606*	-0.00206***	-0.00197***	-0.00136**	-0.000427
	(0.0003)	(0.0003)	(0.0008)	(0.0006)	(0.0006)	(0.0003)
index_interest	-0.00189***	-0.00183***	-0.00635***	-0.00619***	-0.00356***	-0.000957**
	(0.0005)	(0.0004)	(0.0014)	(0.0008)	(0.0007)	(0.0004)
exportshare_sector	-0.0123	0.00743	0.000489	0.0405**	-0.00905	0.00128
	(0.012)	(0.008)	(0.028)	(0.016)	(0.017)	(0.009)
State_share	0.000572	0.000457	0.00578	0.0056	0.00177	-0.000349
	(0.0021)	(0.0020)	(0.0036)	(0.0039)	(0.0038)	(0.0021)
Horizontal FDI	0.0315**	0.0227***	0.0201	-0.0128	0.0176	0.0215**
	(0.014)	(0.009)	(0.035)	(0.017)	(0.016)	(0.008)
Downstream FDI	-0.0127	0.0327	-0.0577	0.0434	0.041	0.0563*
	(0.030)	(0.030)	(0.070)	(0.057)	(0.057)	(0.031)
Upstream FDI	-0.00734	-0.0301***	-0.0156	-0.0713***	-0.0588***	-0.0294***
	(0.008)	(0.008)	(0.016)	(0.016)	(0.016)	(0.009)
Observations	982,142	982,142	982,142	982,142	777,739	777,739

Robust standard errors in parentheses. Dependent variable is either a dummy variable equal to 1 if a new product is introduced by the enterprise in that year or the share of new products in revenues. All specifications include firm fixed effects and time effects. Instruments in the IV specifications for log of output tariff, downstream tariff, and upstream tariff include the WTO dummy interacted with the initial tariff. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table 4: Movements to Sectors with Higher Skilled Worker Share Based on 2004 survey

Dependent variable: Ranking of sector according to skill intensity

	All Enterprises Excluding SOEs and Multinationals		Only Non-Exporters		Only Exporters	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Output_Tariff	-17.51***	-25.96***	-18.54***	-18.80***	-13.00**	-149.1***
	(4.27)	(0.86)	(3.83)	(0.86)	(6.15)	(12.91)
Downstream_Tariff	7.947	-32.95***	7.068	-30.23***	7.174	-129.2***
	(5.01)	(2.10)	(5.42)	(2.54)	(4.97)	(12.12)
Upstream_Tariff	31.66***	108.0***	34.28***	92.21***	24.46*	286.1***
	(11.06)	(3.11)	(10.82)	(3.32)	(12.41)	(22.27)
index_ subsidy	0.649***	0.727***	0.848**	0.883***	0.343	0.44
	(0.23)	(0.12)	(0.33)	(0.15)	(0.27)	(0.37)
index_tax	0.1	0.12	0.174	0.127	-0.300*	0.226
	(0.10)	(0.07)	(0.11)	(0.08)	(0.17)	(0.28)
index_interest	-0.392***	-0.348***	-0.435***	-0.443***	-0.331	-0.276
	(0.146)	(0.085)	(0.146)	(0.097)	(0.206)	(0.304)
Export Share	-192.0***	-183.4***	-207.4***	-201.3***	-165.8***	-94.14***
(Sector Level)	(25.36)	(1.62)	(28.06)	(2.00)	(24.30)	(7.93)
State Share	-0.181	-0.011	-0.441	-0.196	0.485	0.395
	(0.541)	(0.349)	(0.631)	(0.391)	(0.775)	(1.341)
Horizontal FDI	67.92**	43.72***	74.85**	56.62***	59.80**	-79.84***
	(27.50)	(1.57)	(28.18)	(1.76)	(28.39)	(12.42)
Backward FDI	533.0***	590.1***	543.0***	589.5***	498.8***	1,023***
	(106.00)	(5.52)	(118.00)	(6.59)	(89.11)	(45.80)
Forward FDI	(34.610)	-47.92***	(46.110)	-53.15***	-6.004	-148.0***
	(25.59)	(1.38)	(28.71)	(1.65)	(21.27)	(14.14)
Observations	982,143	982,143	777,740	777,740	204,403	204,403

Sectors with a higher rank (number) are more skill intensive. Robust standard error in parenthesis. All regressions include firm fixed effects and time fixed effects.

The coefficient on downstream tariffs in all IV specifications is also negative and significant. Among firms that switch sectors, a tariff reduction in the downstream sector increases the probability that the firm switches to a skill intensive sector. This result is consistent with firms switching sectors by investing in differentiation to escape import competition. The coefficients on downstream and output tariffs have similar magnitudes. This result is consistent with the model where import-competing firms and their input suppliers have the same propensity to invest, and it stands in contrast to the difference in magnitudes in the TFP regressions.

Many of the coefficients reported in Table 4, while not the focus of this paper, are plausible and of interest. The fourth row suggests that a typical firm receiving subsidies moves to a more skill intensive sector by half a sector to a full sector. The large and negative coefficient on sectoral export share indicates that a sector which moved from no exports to 100 percent exports would move down the sectoral ranking by up to 200 steps. The results also suggest that additional foreign investment in the same sector is associated with an improvement in the ranking of 44 to 75 steps, while an increase in foreign investment downstream is associated with a large increase in the quality of suppliers. The coefficient on upstream tariffs is positive, suggesting that a reduction in tariffs on inputs moves the firm down the rank towards less skill-intensive sectors.[22]

Main Findings and Theory It is difficult to reconcile our empirical findings with existing trade models. As discussed in Section 3, the increase in TFP in Tables 1 and 2 is inconsistent with models where economies of scale determine innovation. In recent models with multiproduct firms, such as Bernard et al. (2011) and Mayer et al. (2014), an increase in import competition pushes firms to drop their least productive varieties, not introduce new goods as in Table 3. Switches to more skill-intensive sectors in Table 4 challenge the prediction in the classic Heckscher-Ohlin model that production should shift toward the Chinese comparative advantage, unskill-intensive sectors.[23] So, taken together, the empirical results strongly support the hypothesis that import-competing firms and their input suppliers invest to escape import competition in response to tariff cuts.

[22]The coefficient on input tariffs is inconsistent with findings in the literature that associate access to foreign inputs to technological improvements at the firm level. One reason for this inconsistency is that our input tariffs may be missmeasured since the Chinese government often refunds tariffs on inputs.

[23]Feenstra and Hanson (1997), Burstein et al. (2016), Burstein and Vogel (2016), Fieler et al. (2018), Helpman et al. (2017), among others, explain the increase in demand for skills following a trade liberalization in developing countries. These models work through export expansion or imported inputs (or capital). So, they do not explain the correlation between skill intensity and output tariffs or downstream tariffs.

3.3 Robustness of Empirical Results

We explore further implications of Corollary 8 regarding profit margins, exit, and sector switching. We then perform several robustness checks on the TFP results of Section 3. We explore whether selection could be driving our results, as firms are more likely to exit as reduced tariffs induce greater competition. Finally, we explore the robustness of our results to alternative measures of total factor productivity and to inclusion or exclusion of certain key sectors like textiles and apparel and the computer industry.

Profit Margins (vi) and (vii). We define accounting profits as the establishment level reported gross profits in Chinese currency as a share of establishment revenues.[24] According to the survey, gross profits are revenue minus the cost of goods sold. Table 5 reports the results from regression (13) with accounting margins as the dependent variable. The first three columns include all enterprises, while the next four columns separate the results into non-exporters (columns (4) and (5)) and exporters (columns (6) and (7)). Since the model was developed for firms targeting the domestic market, we expect the results to apply most strongly to the sample of non-exporters.

The coefficient on output tariffs ranges from 0.254 in column (1) to 1.710 in column (4). For firms that do not export, this implies that a two standard deviation reduction in tariffs would lead to a reduction in ROS of between .25 to 1.7 percentage points. Since the average ROS in the sample is five percentage points, this effect is significant but not implausibly large. In contrast, tariffs have no impact on markups for firms oriented towards export markets in columns (5) and (6). In most specifications, output tariffs positively and significantly affect accounting profits, while downstream tariffs have no significant impact on supplier firms. Although the investment in differentiation per se may enter accounting margins, these results are broadly consistent with Corollary 8's prediction that only firms directly competing with imports decrease their profit margins in response to the liberalization.

The coefficients on upstream and downstream tariffs have comparable magnitudes in Tables 3 and 4 where we proxy for the investment in differentiation with the introduction of new goods and shifts to skill-intensive sectors, and they have different coefficients in the regressions on TFP and profit margins which may capture changes in firm markups. This observation is in line with our explanation for the TFP results of Tables 1 and 2: the positive TFP effects of tariffs in import-competing firms may be observationally difficult to identify due to declining revenue from falling markups.

[24] We do not follow De Loecker and Warzynski (2012) in measuring markup, because our model violates their assumptions. DeLoecker and Warzynski themselves point out that their results could be driven by quality upgrading (see page 2441).

Table 5: Accounting Margins and Tariffs

Dependent variable: Reported Gross Profit Margin as a Share of Sales

	All Enterprises Excluding SOEs and Multinationals		Only Non-Exporters		Only Exporters	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
log output_tariff	0.254**	1.596***	0.324**	1.710***	0.093	-0.529
	(0.1160)	(0.3030)	(0.1450)	(0.3040)	(0.1260)	(2.6830)
log downstream_tariff	-0.202	0.66	-0.223	1.177	-0.201	1.068
	(0.1470)	(0.6980)	(0.1740)	(0.8830)	(0.1590)	(2.7910)
log upstream_tariff	0.0186	2.049*	-0.176	1.577	0.37	1.322
	(0.3050)	(1.0460)	(0.3930)	(1.1210)	(0.2750)	(5.2250)
index_subsidy	0.792***	0.793***	0.944***	0.941***	0.429***	0.420***
	(0.0571)	(0.0356)	(0.0663)	(0.0468)	(0.0629)	(0.0510)
index_tax	2.931***	2.929***	3.018***	3.017***	2.482***	2.481***
	(0.1410)	(0.0209)	(0.1590)	(0.0244)	(0.1170)	(0.0433)
index_interest	0.036	0.0329	0.0397	0.0381	0.0257	0.0291
	(0.0304)	(0.0215)	(0.0327)	(0.0254)	(0.0605)	(0.0414)
State_share	-0.281**	-0.249*	-0.366***	-0.331**	-0.115	-0.104
	(0.1220)	(0.1330)	(0.1330)	(0.1520)	(0.2610)	(0.3060)
Horizontal FDI	-1.061	-3.399***	-1.273	-3.898***	-1.047*	-2.534
	(0.694)	(0.473)	(0.902)	(0.572)	(0.578)	(1.825)
Downstream FDI	-0.121	-3.840**	1.047	-3.677*	0.0225	-3.36
	(1.755)	(1.765)	(2.387)	(2.190)	(1.624)	(10.810)
Upstream FDI	0.155	2.477***	0.407	2.952***	0.247	0.0176
	(0.372)	(0.509)	(0.508)	(0.608)	(0.270)	(3.217)
Observations	981,001	981,001	776,775	776,775	204,226	204,226

Standard errors are clustered. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.
All regressions include firm fixed effects and time fixed effects.

Table 6: Probit Regression of Whether or Not Establishment Switched Sector

	All enterprises	Non-Exporters	Exporters
	(1)	(2)	(3)
output_tariff	-0.0117*	-0.00131	-0.0720***
	(0.0070)	(0.0080)	(0.0143)
downstream_tariff	-0.161***	-0.179***	-0.00749
	(0.0111)	(0.0127)	(0.0243)
upstream_tariff	-0.155***	-0.205***	-0.0401
	(0.0140)	(0.0157)	(0.0307)
index_subsidy	0.133***	0.138***	0.0800***
	(0.0090)	(0.0109)	(0.0165)
index_tax	-0.0169***	-0.0144**	-0.0135
	(0.0063)	(0.0072)	(0.0134)
index_interest	-0.0449***	-0.0346***	-0.0635***
	(0.0067)	(0.0077)	(0.0136)
exportshare_sector	0.167***	0.312***	-0.468***
	(0.031)	(0.039)	(0.058)
State_share	-0.177***	-0.136***	-0.376***
	(0.0279)	(0.0316)	(0.0602)
Horizontal FDI	-0.212***	-0.167***	-0.437***
	(0.053)	(0.061)	(0.107)
Downstream FDI	2.291***	2.370***	2.121***
	(0.114)	(0.133)	(0.225)
Upstream FDI	0.287***	0.294***	0.233***
	(0.030)	(0.035)	(0.057)
Observations	931,429	736,941	194,488

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

Sector Switching (iv). Table 6 tests the prediction of Corollary 8(iv) that tariff reductions increase the probability that firms switch sectors. The dependent variable is a dummy variable equal to 1 if the enterprise switches from one two-digit sector to another. Recall that we have 71 of these two digit sectors that have been normalized to take into account classification changes over the sample period. We estimate a probit regression and report the results for all enterprises, non-exporters, and exporters. The results indicate that enterprises are more likely to switch sectors if tariffs fall, although the effects are less strong for output tariffs. For downstream tariffs, the results suggest that a one standard deviation reduction in downstream tariffs would increase the probability of sector switching by 8 to 9 percentage points. Note that trade shifts production across sectors also in the classical models of Ricardo and Heckscher-Ohlin. It is thus the switch toward skill-intensive sectors of Table 4 above that distinguishes our model from these classical models.

Other results in Table 6 are of interest. The positive coefficient on subsidies indicates that firms receiving subsidies are more likely to switch sectors. Conversely, firms receiving tax breaks or low interest loans are less likely to switch sectors. Firms in sectors with a high share of export activity are more likely to switch sectors unless they are exporters; if they export, then firms in export-intensive sectors are less likely to switch. Firms in sectors with a high share of foreign investment are less likely to switch sectors. However, firms supplying to foreign firms or firms in sectors with a high share of foreign suppliers are more likely to switch sectors.

Exit (i). Appendix Table A.3 tests the prediction of Corollary 8(i) that import competition increases the probability of firm exit. While the probit estimates in the first three columns of the table are reported for completion, we focus on the linear probability model in the last three columns where we instrument tariffs with initial tariffs interacted with the WTO dummy. The coefficients on output tariffs and downstream tariffs are negative, indicating that a reduction in tariffs raises the probability of exit for import-competing firms and their suppliers. In contrast, the coefficient on upstream tariffs is positive and significant, indicating that a reduction in tariffs on inputs reduces the probability of exit. The coefficients on downstream and output tariffs are largest when we restrict the sample to non-exporters who do not switch sectors in the last column. The coefficients indicate that a one standard deviation reduction in tariffs would increase the probability of exit by 4.2 percent for output tariffs, and by nearly 20 percent for downstream tariffs. A one standard deviation reduction in upstream tariffs would reduce exit by nearly 15 percent.

3.3.1 Robustness of TFP Results

Appendix Tables A.4 through A.8 explores the robustness of our TFP results of Tables 1 and 2. In Table A.4, we test whether the results are affected by multicollinearity. We explore whether the coefficients change if we only put in tariffs one at a time. This extension is important in case the multicollinearity between final goods and downstream tariffs (their correlation is around .5) drive the lower coefficient on final goods tariffs. Multicollinearity does not seem to be a problem, as the coefficient magnitudes are generally unaffected by entering tariffs into the equation one at a time.

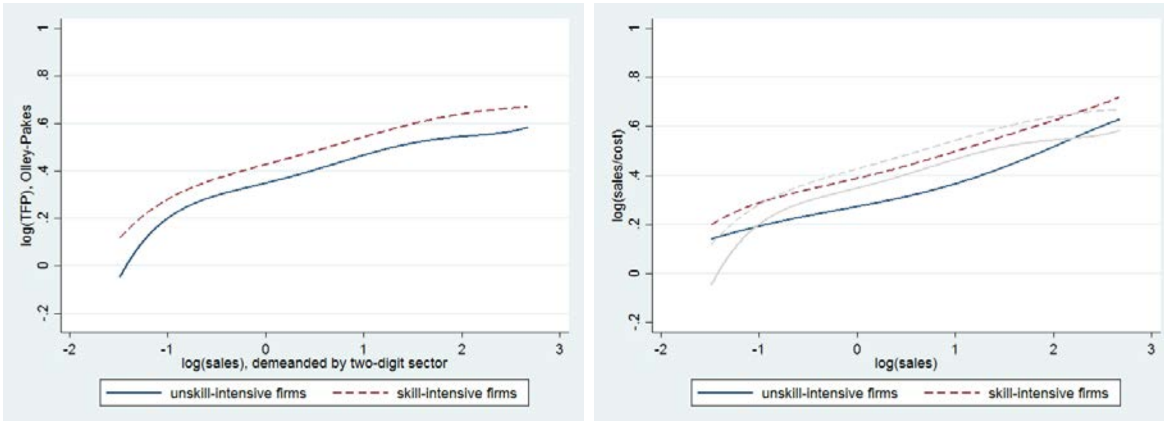
Tables A.5 and A.6 explore the importance of selection in our results. Following Wooldridge (2002), we test for survivorship bias by including a lead of the selection indicator $s_{i,t+1}$ in our estimating equations, where $s_{i,t+1}$ is equal to 0 for firms that do not exit the sample and switches from 0 to 1 in the period just before attrition. The coefficient on the lead of the selection indicator was negative and significant in our TFP regressions. This negative coefficient on the "pre-exit" dummy suggests that firms that are likely to exit the sample are less productive. These results are not surprising and are consistent with a number of studies. To test whether selection affected our core results, we performed two tests. The first test is to retain all enterprises that were present in all years in the sample. By creating this so-called balanced panel, we eliminated ninety percent of the sample, and only retain 65,239 observations because the vast majority of enterprises do not have a complete time series. With this much smaller sample, we repeat the main specification from Table 1 and report the results in Appendix Table A.5. The results are remarkably consistent with our first set of results. Output and downstream tariffs negatively affect productivity, with magnitudes almost ten times larger for downstream tariffs than output tariffs.

For our second test, we follow Wooldridge (2010) and construct a Heckman-type correction in the context of a panel dataset with firm fixed effects. In the context of panel data with an unobserved firm fixed effect and attrition, Wooldridge proposes as a solution a variant of a two-stage Heckman correction. In each period, Wooldridge proposes estimating a selection equation using a probit approach and calculating lambda, the inverse Mills ratio, for each parent i. Once a series of lambdas has been estimated for each year and parent, the estimating equations are augmented by these lambdas. This approach is successful only if we can identify determinants of the binary selection variable set before the firm exits the sample (in period t-1) that do not belong in the estimating equation. We identify candidate variables using the insights from models where heterogeneity in productivity is a significant determinant of whether firms enter into international trade or foreign investment (see Melitz (2003)). In these models, only the most profitable firms survive. Since we already control for output and factor price shocks using a variety of input and output price deflators, we use the establishment's profitability in the previous period as the determinant of survival that does not appear in the estimating equation.

Appendix Table A.6 reports the second-stage estimates using this two-step approach. The first four columns include all observations, while the last two columns include only non-exporters. The sample size decreases, since implementing the selection correction eliminates the first time-series observation for each firm. The coefficients on the inverse Mills ratios are statistically significant across all specifications, indicating that selection could have biased the results. Nonetheless, adding the inverse Mills ratio to control for selection does not change the sign and barely changes the point estimates of the coefficients of interest.

Last, Appendix Table A.7 has three components. We first explore the robustness of the results to dropping some key sectors. There were major liberalizations in textiles and apparel during this period, such as the phasing out of the Multi-fibre Agreement (MFA). A potential concern is that the textile and apparel sectors play a major role in our results. To address this point, columns (1) and (2) drop those sectors and show that our main results are unaffected. The results also hold in Columns (3) and (4), which repeat this exercise but instead drop the computer and computer peripherals sector. These sectors experienced large growth due to offshoring. The last two columns explore the robustness of the results to including tariffs in the first stage of the TFP estimation using Olley and Pakes. One critique of the Olley-Pakes procedure is that policy variables influence the firms' decisions on input usage. By excluding policy variables from the first stage, the Olley-Pakes estimates of the key factor share parameters on labor, capital, and materials would have an omitted-variable bias. The last two columns of Appendix Table A.7 indicate that adding policy variables to the OP first stage does not significantly affect the TFP results.

The last robustness test, with results reported in Appendix Table A.7, uses an alternative TFP estimation strategy to OP. In particular, we implement Caves, Fraser, and Ackerberg (ACF) and test the robustness of the TFP results to this alternative strategy. ACF argue that there are some key shortcomings to OP, particularly in terms of identification of parameters of the production function. Using their approach, we show that our results are robust to alternative measurement strategies for TFP.



(a) Data (b) Model

Figure 3: Polynomial Fit of TFP and sales

4 Calibration

This section calibrates some parameters of the model to get a sense of magnitude for the new gain from trade: investing in differentiation. The key moments of the data used are illustrated in Figure 3(a). Using the 2004 cross-section, where skill-intensity is observed, we split the sample into the 20 percent most skill-intensive firms and the remaining firms. For each of these subsets, Figure 3(a) shows a polynomial fit of TFP as a function of sales (in logs).[25] In line with Assumption 1, skill intensive firms have higher TFP than unskill-intensive firms.

Like Edmond, Midrigan, Xu (2015 EMX), we set the elasticity of substitution within nests $\sigma = 10$. Assume that the unobserved distribution of firms across nests follows a Poisson distribution. To match Figure 3(a), we allow the parameter of the Poisson distribution to be different between skill-intensive and unskill-intensive firms. Denote these parameters with λ_S and λ_U. We simulate 100,000 firms. For each simulated firm, we randomly draw its sales from the observed distributions of sales. We use the sales of unskill-intensive firms in the data for 80,000 firms, and the sales of skill-intensive firms for the remaining 20,000 firms. For each guess of the parameters, we group these firms into nests according to the Poisson distributions with parameters λ_S, λ_U. Given sales, nests and parameters σ and η, the markup of each firm is given by equation (3). For each firm, we calculate TFP in the model as sales divided by variable plus fixed cost. The variable

[25] We use a polynomial of fifth order and exclude firms with the lowest and highest one percentile of the distribution of sales. The level of the logarithm of TFP measures is not meaningful. We normalize it so that the unskill intensive firm at the fifth percentile of the sales distribution has a TFP of around 0.10, in line with the normalization $\sigma = 10$ below.

cost is sales over markup. We take the fixed cost to be the profit of the firm at the one percentile of the distribution of sales. Like in other heterogeneous-firm models, this cost has to be smaller than the profits of the smallest existing firms.

This simulation procedure gives us vectors of sales and TFP for 80,000 unskill-intensive firms and 20,000 skill-intensive firms. We choose parameters λ_S, λ_U, and η to match the polynomial regression of TFP on sales in Figure 3(a).[26] The fit of the model appears in Figure 3(b). In light gray are the data curves for easier visualization. The parameter estimates are extremely close to EMX. The elasticity of substitution across nests is $\eta = 1.19$ in our model and 1.28 in their model using Taiwanese data. The Poisson parameters are $\lambda_S = 1.88$ and $\lambda_U = 2.69$ implying, like EMX, that the largest firms in most nests have 40% or 45% market shares while the smallest firms face elasticities close to σ.[27] Note that even though we did not simulate the full strategic game of Section 2, the model can always rationalize the estimated joint distribution of TFP and sales if the fixed cost to produce a differentiated variety is heterogeneous across firms.

We conduct a simple counterfactual where we mechanically shift one percent of firms from existing nests with more than one competitor to new nests. For such, we normalize $\overline{P} = 1$. We calculate the price index of a nest as $P_n = (\text{total sales}_n)^{1/(1-\eta)}$ and the marginal cost of each firm as $c_i/\phi_i = s_i^{1/(1-\sigma)} P_n/\mu_i$ where s_i is its market share and μ_i its markup. We then eliminate 1000 firms (one percent of firms) randomly from nests with more than one firm, and increase the number of differentiated firms by 1000. We use c_i/ϕ_i to estimate new price indices P_n for nests whose number of firms decreased, and we assume that the newly differentiated firms get the same distribution of c_i/ϕ_i as differentiated firms in the estimated model (firms alone in a nest). The gross welfare gain from this exercise is 4.9 percent, but part of this gain may come from fixed costs. If we subtract from the gross welfare gain the change in the profit of investing firms, the gain reduces to 4.1 percent. In sum, 4.9 percent is an upper bound on the gains from differentiation which occurs if the investment cost is zero $f_D = f_0$, and 4.1 percent is a lower bound that occurs if investing firms are indifferent between investing or not.

This welfare gain is large because the investment in differentiation gives the consumer access to new types of goods, not previously offered.[28] One percent of firms shift from an elasticity of substitution with respect to their closest competitor of $\sigma = 10$ to an elasticity

[26]For both skilled and unskilled firms, we match the the fitted value of the polynomial of fifth order for the following percentiles of the sales distribution: 1, 5, 10, 25, 50, 75, 90, 95, 99. The values of these moments, in the data and in the model, are in Appendix F.

[27]Because there are no nests with zero firms, the average number of firms per nests is greater than λ.

[28]To get a sense of magnitude, the effect from increasing the mass of firms in a standard price index is $M^{1/(1-\sigma)}$ where M is the mass of firms and σ the elasticity of substitution.

of $\eta = 1.19$. Private profits do not fully eliminate these welfare gains because there is profit stealing among less-differentiated firms. The profits of firms that remain in the non-differentiated nests increase. If creating new nests becomes increasingly expensive or if some investing firms imitate and enter existing nests, the net welfare gain may decrease below 4.1 percent. We do not know the extent to which import competition led Chinese firms to invest in differentiation—tailoring their goods to domestic tastes and improving customization and non-tradable services. Yet, this stylized calibration and counterfactual show that the welfare gains from investing in differentiation can be substantial.

5 Concluding Comments

This paper proposes a new gain from trade: firms invest to differentiate their products when import competition tightens. We provide evidence that this gain accrues both to import-competing firms and to their suppliers. Tariff reductions increase the productivity of both of these sets of firms, and the changes are generally larger for suppliers facing a cut in downstream tariffs than for firms directly competing with imports. Although measured productivity is the standard measure of firm performance, changes in productivity in the model arise from the investment in differentiation and from a pro-competitive effect on markups.

This observation leads us to search for evidence of the investment in differentiation using other firm outcomes. Tariff reductions increase the probability that both import-competing firms and their input suppliers switch to more skill-intensive sectors and introduce new products. These results together are inconsistent with previous models of international trade—the classic model of factor proportions as well as more recent models of heterogeneous firms with multiple products. So, together, they provide evidence for our mechanism: Firms escape import competition by differentiating their products and creating new market niches. As firms differentiate, they push their suppliers to also invest in differentiation, introduce new products and switch to skill-intensive sectors.

While previous work on unilateral trade reforms has measured the impact of output tariffs and input (upstream) tariffs on firm performance, to our knowledge this is the first paper to study the impact of downstream tariffs on firm performance. This link between the productivity of upstream and downstream appears in previous work on foreign direct investment. For the Chinese experience, the effect of tariff cuts on productivity was larger for input suppliers than for firms directly competing with imports. We also find this link between upstream and downstream firms to be relevant for other firm outcomes, such as the introduction of new goods and skill intensity, used before to study the direct effect of import competition and foreign inputs. By putting these elements together and focusing on import-competing firms and their suppliers, this paper brings us closer to a more complete picture of the effects of international trade on firms.

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Escaping import competition and Downstream Tariffs

Appendix

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Contents

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A Additional Empirical Results

This Appendix presents additional empirical results. Table A.1 reports the coefficients on all control variables of Table 2 in the main text. 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"). These policies are self-reported by the firm in the survey. 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. We refer the reader to the main text for explanations on the remaining Tables A.2 through A.8.

Table A.1: Basic regressions including SOE's and Firms with Minority Foreign Ownership and lagged tariffs

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

	All Enterprises				Only Non-Exporters	
	OP	FE	OP	FE	OP	OP
	OLS	OLS	IV	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0285***	-0.0297***	-0.0421***	-0.0372***	-0.0329***	-0.0520***
	(0.0067)	(0.0070)	(0.0108)	(0.0111)	(0.0078)	(0.0114)
downstream_tariff	-0.0245*	-0.0254*	-0.117**	-0.123**	-0.0319**	-0.573***
	(0.0135)	(0.0146)	(0.0515)	(0.0520)	(0.0151)	(0.0739)
upstream_tariff	-0.0195	-0.019	-0.737***	-0.814***	-0.00961	-0.413***
	(0.0175)	(0.0188)	(0.0690)	(0.0702)	(0.0181)	(0.0710)
index_subsidy	0.00783***	0.00972***	0.00633***	0.00806***	0.00644***	0.00480***
	(0.0015)	(0.0015)	(0.0012)	(0.0012)	(0.0021)	(0.0016)
index_tax	0.0239***	0.0245***	0.0243***	0.0250***	0.0234***	0.0238***
	(0.0011)	(0.0011)	(0.0008)	(0.0008)	(0.0011)	(0.0010)
index_interest	-0.00596***	-0.00711***	-0.00497***	-0.00605***	-0.00794***	-0.00694***
	(0.0013)	(0.0013)	(0.0009)	(0.0009)	(0.0012)	(0.0011)
exportshare_sector	0.128	0.151	0.521***	0.577***	0.148	0.641***
	(0.154)	(0.160)	(0.038)	(0.039)	(0.184)	(0.052)
State_share	-0.0195***	-0.0184***	-0.0240***	-0.0233***	-0.0185***	-0.0218***
	(0.0032)	(0.0036)	(0.0030)	(0.0030)	(0.0038)	(0.0035)
Horizontal FDI	0.0109	0.0193*	0.00657	0.0144	0.00176	-0.00234
	(0.010)	(0.010)	(0.010)	(0.011)	(0.017)	(0.017)
Downstream FDI	0.15	0.2	-0.0265	0.00927	0.232	0.0767**
	(0.197)	(0.213)	(0.026)	(0.027)	(0.228)	(0.033)
Upstream FDI	1.394	1.294	2.223***	2.227***	1.211	1.572***
	(0.851)	(0.914)	(0.141)	(0.145)	(0.881)	(0.167)
Change in four-digit sector	0.218	0.205	0.330***	0.343***	-0.0353	0.209***
	(0.4070)	(0.4040)	(0.0475)	(0.0482)	(0.4920)	(0.0606)
Observations	821,970	821,970	821,970	821,970	619,448	619,448

Standard errors are clustered. All specifications include fixed effects for the firm, time, and two-digit sector. All specifications also include a dummy variable equal to 1 if the firm changes a four digit sector as well. IV estimates use initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments. Tariffs are lagged and regressions include state-owned enterprises, and firms with minority foreign ownership. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.2: Basic Regressions of Productivity on Tariffs without Sector Fixed Effect

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

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
	OP	FE	OP	FE	OP	FE
	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Output_tariff	0.0269	-0.00214	-0.00601	-0.00709	-0.0467***	-0.0296***
	(0.0218)	(0.0184)	(0.0115)	(0.0113)	(0.0116)	(0.0114)
Downstream_tariff	-0.0721	-0.108**	-0.0163	-0.101***	-0.239***	-0.285***
	(0.0524)	(0.0506)	(0.0268)	(0.0252)	(0.0327)	(0.0315)
Upstream_tariff	-0.117	0.0916	-0.533***	-0.382***	-0.366***	-0.289***
	(0.0754)	(0.0613)	(0.0431)	(0.0422)	(0.0470)	(0.0457)
Index_subsidy	0.00895***	0.0126***	0.00838***	0.0118***	0.00658***	0.00925***
	(0.0018)	(0.0016)	(0.0013)	(0.0012)	(0.0016)	(0.0015)
Index_tax	0.0213***	0.0219***	0.0213***	0.0217***	0.0211***	0.0218***
	(0.0009)	(0.0009)	(0.0008)	(0.0008)	(0.0009)	(0.0009)
Index_interest	-0.0134***	-0.0150***	-0.0134***	-0.0151***	-0.0153***	-0.0168***
	(0.0016)	(0.0014)	(0.0009)	(0.0009)	(0.0010)	(0.0010)
Export_share_sector	0.688***	0.368**	0.828***	0.550***	1.131***	0.807***
	(0.191)	(0.152)	(0.024)	(0.023)	(0.032)	(0.030)
State_share	-0.00118	-0.000976	-0.00327	-0.00287	-0.000755	0.0000239
	(0.0039)	(0.0039)	(0.0042)	(0.0041)	(0.0047)	(0.0046)
Horizontal FDI	0.199	0.298*	0.345***	0.466***	0.334***	0.483***
	(0.173)	(0.172)	(0.026)	(0.024)	(0.030)	(0.028)
Downstream FDI	1.05	2.131***	1.149***	2.396***	1.296***	2.621***
	(0.737)	(0.578)	(0.092)	(0.085)	(0.112)	(0.108)
Upstream FDI	0.542**	0.500***	0.478***	0.450***	0.364***	0.341***
	(0.211)	(0.112)	(0.023)	(0.021)	(0.029)	(0.026)
Observations	982,142	982,142	982,142	982,142	777,739	777,739

Standard errors are clustered. Tariffs and TFP are in logs. Different from Table 1 in the text, the table does not have sector fixed effect or a dummy for whether the firm changes its four-digit sector. IV estimates use initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.3: Determinants of Exit

	All enterprises (1)	Non-Exporters (2)	Exporters (3)
output_tariff	-0.0597***	-0.0541***	-0.0885***
	(0.0137)	(0.0137)	(0.0140)
downstream_tariff	-0.284***	-0.307***	-0.372***
	(0.0359)	(0.0399)	(0.0454)
upstream_tariff	0.249***	0.266***	0.292***
	(0.0522)	(0.0580)	(0.0578)
index_subsidy	-0.0303***	-0.0303***	-0.0282***
	(0.0016)	(0.0016)	(0.0020)
index_tax	-0.00529***	-0.00552***	-0.00693***
	(0.0010)	(0.0011)	(0.0012)
index_interest	0.0142***	0.0135***	0.0138***
	(0.0012)	(0.0012)	(0.0014)
exportshare_sector	0.192***	0.225***	0.266***
	(0.024)	(0.027)	(0.032)
State_share	0.0024	0.0013	-0.002
	(0.0052)	(0.0052)	(0.0060)
Horizontal FDI	-0.146***	-0.136***	-0.160***
	(0.025)	(0.025)	(0.029)
Downstream FDI	0.581***	0.506***	0.602***
	(0.085)	(0.094)	(0.105)
Upstream FDI	-0.133***	-0.154***	-0.210***
	(0.022)	(0.023)	(0.028)
Observations	807,820	777,512	634,245

Liner probability model with IV. Dependent variable is is a zero-one dummy variable for whether or not the enterprise exits in the next period. All specifications include firm and time effects. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.4: Testing for Multicollinearity

Dependent variable: TFP measured à la Olley-Pakes (OP)

	(1)	(2)	(3)	(4)
output_tariff	-0.015	-0.0197*		
	(0.0105)	(0.0107)		
downstream_tariff			-0.177***	-0.115***
			(0.0289)	(0.0349)
upstream_tariff	-0.551***	-0.624***	-0.483***	-0.586***
	(0.0410)	(0.0570)	(0.0337)	(0.0508)
index_subsidy	0.00664***	0.0108***	0.00607***	0.0105***
	(0.0016)	(0.0012)	(0.0016)	(0.0012)
index_tax	0.0214***	0.0211***	0.0212***	0.0209***
	(0.0009)	(0.0008)	(0.0009)	(0.0008)
index_interest	-0.0153***	-0.0129***	-0.0156***	-0.0129***
	(0.0010)	(0.0009)	(0.0010)	(0.0009)
exportshare_sector	1.000***	0.567***	1.101***	0.635***
	(0.026)	(0.033)	(0.030)	(0.035)
State_share	-0.00117	-0.00259	-0.000365	-0.00222
	(0.0047)	(0.0042)	(0.0047)	(0.0042)
Horizontal FDI	0.374***	0.177***	0.355***	0.184***
	(0.030)	(0.027)	(0.028)	(0.026)
Downstream FDI	0.866***	1.269***	1.017***	1.390***
	(0.093)	(0.123)	(0.104)	(0.145)
Upstream FDI	0.463***	0.369***	0.407***	0.394***
	(0.025)	(0.031)	(0.023)	(0.026)
Observations	777,739	863,363	785,458	872,225
Exclude exporters?	yes	no	yes	no
Keep only enterprises that do not switch sectors?	no	yes	no	yes

Standard errors are clustered. All specifications include fixed effects for the firm and time. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.5: Regressions keeping only a balanced panel of firms

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

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
	OP	FE	OP	FE	OP	OP
	OLS	OLS	IV	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0535***	-0.0560***	-0.0345**	-0.0340*	-0.0608***	-0.0628***
	(0.0131)	(0.0143)	(0.0172)	(0.0181)	(0.0148)	(0.0184)
downstream_tariff	-0.0616	-0.0674	-0.303***	-0.285***	-0.0707	-0.633***
	(0.0487)	(0.0560)	(0.0794)	(0.0804)	(0.0536)	(0.1140)
upstream_tariff	-0.105	-0.126	-0.326***	-0.454***	-0.0789	-0.137
	(0.0677)	(0.0771)	(0.0953)	(0.0974)	(0.0764)	(0.1070)
index_subsidy	0.0116***	0.0144***	0.00927***	0.0116***	0.00931***	0.00556
	(0.0033)	(0.0034)	(0.0027)	(0.0028)	(0.0032)	(0.0037)
index_tax	0.0162***	0.0160***	0.0161***	0.0161***	0.0158***	0.0146***
	(0.0030)	(0.0030)	(0.0021)	(0.0022)	(0.0040)	(0.0027)
index_interest	-0.00192	-0.00335	-0.0024	-0.00383*	-0.00365	-0.00438
	(0.0031)	(0.0030)	(0.0023)	(0.0023)	(0.0033)	(0.0030)
exportshare_sector	0.394**	0.442**	0.695***	0.772***	0.491**	0.905***
	(0.165)	(0.175)	(0.065)	(0.067)	(0.230)	(0.091)
State_share	0.0169	0.017	0.0189	0.0189	0.0289**	0.0326**
	(0.0129)	(0.0130)	(0.0129)	(0.0129)	(0.0130)	(0.0143)
Horizontal FDI	0.135	0.193	0.134**	0.183***	0.181	0.178**
	(0.247)	(0.269)	(0.053)	(0.055)	(0.285)	(0.071)
Downstream FDI	1.564	1.669	2.528***	2.660***	1.345	2.961***
	(1.033)	(1.189)	(0.303)	(0.320)	(1.091)	(0.409)
Upstream FDI	0.131	0.151	0.312***	0.340***	0.00118	0.229**
	(0.434)	(0.442)	(0.084)	(0.086)	(0.524)	(0.113)
Observations	65,239	65,239	65,239	65,239	46,655	46,655

Notes: Robust standard errors in parentheses. Dependent variable is log TFP. Only retains observations where establishments are present in all years. All specifications include time effects and 2-digit Sector Dummies. Instruments in the IV specifications for lnTariff, ln downstream Tariff, and ln upstream tariff include the WTO dummy interacted with the initial tariff. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.6: Controlling for Selection by Including the Inverse Mills Ratio

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

	All Enterprises Excluding SOEs and Multinationals				Only Non-Exporters	
	OP	FE	OP	FE	OP	OP
	OLS	OLS	IV	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0336***	-0.0355***	-0.0218**	-0.0203*	-0.0381***	-0.0252**
	(0.0074)	(0.0080)	(0.0104)	(0.0106)	(0.0085)	(0.0106)
downstream_tariff	-0.128*	-0.132*	-0.163***	-0.168***	-0.155**	-0.498***
	(0.0660)	(0.0754)	(0.0532)	(0.0533)	(0.0726)	(0.0675)
upstream_tariff	-0.0575	-0.0652	-0.345***	-0.449***	-0.0395	-0.173**
	(0.0416)	(0.0496)	(0.0756)	(0.0765)	(0.0425)	(0.0740)
index_subsidy	-0.0227***	-0.0215***	-0.0234***	-0.0224***	-0.0241***	-0.0244***
	(0.0024)	(0.0024)	(0.0014)	(0.0014)	(0.0028)	(0.0017)
index_tax	0.0324***	0.0330***	0.0322***	0.0327***	0.0326***	0.0320***
	(0.0011)	(0.0011)	(0.0008)	(0.0008)	(0.0010)	(0.0010)
index_interest	0.00478***	0.00442**	0.00516***	0.00493***	0.00338**	0.00339***
	(0.0017)	(0.0017)	(0.0010)	(0.0010)	(0.0016)	(0.0011)
exportshare_sector	0.167	0.205	0.311***	0.391***	0.198	0.404***
	(0.130)	(0.137)	(0.027)	(0.028)	(0.162)	(0.036)
State_share	0.0288***	0.0304***	0.0285***	0.0300***	0.0302***	0.0298***
	(0.0047)	(0.0046)	(0.0039)	(0.0039)	(0.0056)	(0.0044)
Horizontal FDI	0.187	0.225	0.168***	0.200***	0.224	0.212***
	(0.186)	(0.203)	(0.022)	(0.023)	(0.205)	(0.027)
Downstream FDI	1.18	1.177	1.316***	1.353***	1.052	1.147***
	(0.864)	(1.002)	(0.108)	(0.109)	(0.897)	(0.128)
Upstream FDI	0.107	0.115	0.176***	0.203***	-0.00984	0.137***
	(0.380)	(0.388)	(0.038)	(0.038)	(0.411)	(0.046)
Mills	-0.367***	-0.355***	-0.744***	-0.784***	-0.392***	-0.693***
	(0.042)	(0.042)	(0.022)	(0.022)	(0.044)	(0.025)
Mills99	0.014	0.014	0.390***	0.440***	0.023	0.329***
	(0.043)	(0.045)	(0.027)	(0.027)	(0.045)	(0.031)
Mills00	0.045	0.030	0.409***	0.442***	0.049	0.354***
	(0.047)	(0.048)	(0.027)	(0.027)	(0.053)	(0.031)
Mills01	-0.117***	-0.132***	0.254***	0.289***	-0.0839*	0.237***
	(0.038)	(0.040)	(0.026)	(0.026)	(0.043)	(0.031)
Mills02	(0.008)	(0.028)	0.384***	0.421***	0.028	0.353***
	(0.042)	(0.043)	(0.025)	(0.025)	(0.043)	(0.029)
Mills03	0.042	0.020	0.427***	0.459***	0.0765*	0.391***
	(0.042)	(0.042)	(0.024)	(0.024)	(0.044)	(0.027)
Mills04	(0.053)	-0.0888*	0.299***	0.307***	(0.045)	0.236***
	(0.049)	(0.052)	(0.024)	(0.024)	(0.046)	(0.029)
Mills05	-0.296***	-0.340***	0.0843***	0.0932***	-0.256***	0.0530**
	(0.054)	(0.059)	(0.021)	(0.021)	(0.059)	(0.024)
Mills06	-0.382***	-0.436***			-0.333***	
	(0.063)	(0.068)			(0.067)	
Observations	806,766	806,766	806,766	806,766	633,360	633,360

Notes: Specification is the same as Table 1, with added controls for the inverse Mills ratio. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Table A.7: Other Robustness Checks

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

	Dropping Textiles and Apparel		Dropping Computers and Peripherals		Including Policy Variables the First Stage of OP Estimates	
	OP	FE	OP	FE	OP	FE
	(1)	(2)	(3)	(4)	(5)	(6)
output_tariff	-0.0699***	-0.0715***	-0.0477***	-0.0458***	-0.0469***	-0.0456***
	(0.0119)	(0.0122)	(0.0109)	(0.0112)	(0.0111)	(0.0112)
downstream_tariff	-0.504***	-0.562***	-0.174***	-0.170***	-0.142***	-0.171***
	(0.0485)	(0.0489)	(0.0371)	(0.0372)	(0.0377)	(0.0373)
upstream_tariff	-0.241***	-0.321***	-0.350***	-0.461***	-0.414***	-0.458***
	(0.0503)	(0.0511)	(0.0609)	(0.0619)	(0.0619)	(0.0620)
index_subsidy	0.00921***	0.0112***	0.0102***	0.0122***	0.0126***	0.0123***
	(0.0013)	(0.0013)	(0.0011)	(0.0011)	(0.0011)	(0.0011)
index_tax	0.0218***	0.0221***	0.0213***	0.0217***	0.0220***	0.0216***
	(0.0008)	(0.0009)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
index_interest	-0.0123***	-0.0137***	-0.0121***	-0.0133***	-0.0139***	-0.0132***
	(0.0009)	(0.0009)	(0.0008)	(0.0008)	(0.0008)	(0.0008)
exportshare_sector	0.333***	0.391***	0.384***	0.474***	0.395***	0.479***
	(0.025)	(0.025)	(0.030)	(0.030)	(0.030)	(0.031)
State_share	0.0000315	0.000568	-0.0018	-0.00133	-0.00027	-0.00144
	(0.0042)	(0.0042)	(0.0039)	(0.0039)	(0.0039)	(0.0039)
Horizontal FDI	0.152***	0.223***	0.156***	0.212***	0.134***	0.198***
	(0.024)	(0.025)	(0.022)	(0.022)	(0.022)	(0.022)
Downstream FDI	2.466***	2.492***	1.704***	1.638***	1.632***	1.560***
	(0.167)	(0.171)	(0.148)	(0.149)	(0.150)	(0.149)
Upstream FDI	0.126***	0.136***	0.144***	0.169***	0.141***	0.178***
	(0.036)	(0.036)	(0.036)	(0.037)	(0.037)	(0.037)
Observations	800,420	800,420	981,733	981,733	982,142	982,142

Notes: Robustness checks on table 1. All specifications use IV and include all enterprises, excluding SOE's and multinationals. All specifications estimated with firm fixed effects and clustered standard errors. All specifications include 2 digit sector dummies and time dummies. All specifications also include a dummy variable equal to 1 if the firm changes a four digit sector as well. Instrumental variables are initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments.

Table A.8: Productivity Measure of Ackerberg, Caves, Frazer (2015)

Dependent variable: TFP measured following Ackerberg, Caves, Frazer (2015)

	All Enterprises Excluding SOEs and Multinationals		Only Non-Exporters	
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
output_tariff	-0.0634***	-0.135***	-0.0694***	-0.185***
	(0.0209)	(0.0279)	(0.0239)	(0.0282)
downstream_tariff	-0.0419	-0.598***	-0.0403	-1.297***
	(0.1700)	(0.0711)	(0.1770)	(0.0874)
upstream_tariff	-0.375*	-0.935***	-0.400*	-0.537***
	(0.1940)	(0.1270)	(0.2120)	(0.1360)
index_subsidy	0.0100***	0.00837***	0.00773**	0.00459*
	(0.0037)	(0.0021)	(0.0037)	(0.0027)
index_tax	0.0278***	0.0271***	0.0287***	0.0266***
	(0.0046)	(0.0013)	(0.0051)	(0.0016)
index_interest	-0.0154***	-0.0150***	-0.0165***	-0.0159***
	(0.0049)	(0.0015)	(0.0061)	(0.0018)
exportshare_sector	0.554*	1.400***	0.692*	1.778***
	(0.309)	(0.059)	(0.387)	(0.079)
State_share	-0.00152	-0.00271	0.0027	0.00359
	(0.0068)	(0.0070)	(0.0078)	(0.0080)
Horizontal FDI	1.226*	1.213***	1.455*	1.552***
	(0.664)	(0.049)	(0.736)	(0.064)
Downstream FDI	-2.342	-0.442	-2.828	0.955**
	(2.249)	(0.299)	(2.314)	(0.377)
Upstream FDI	-0.503	-0.329***	-0.848	-0.610***
	(0.849)	(0.073)	(0.931)	(0.079)
Observations	980,963	980,963	776,922	776,922

Notes: All specifications estimated with firm fixed effects and clustered standard errors. All specifications include 2 digit sector dummies and time dummies. All specifications also include a dummy variable equal to 1 if the firm changes a four digit sector as well. IV estimates use initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments.

Table B.1: Cross-sectional relation between revenue and TFP
Dependent variable is log TFP, measured à la Olley-Pakes (OP) or OLS with fixed effects (FE)

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

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

B Tariffs, TFP and Revenue

This appendix presents empirical results on the cross-sectional relation between revenue and TFP, and on the effect of tariffs on firm revenue. As mentioned in the main text, a large class of models explain the relationship between trade and technology through the economies-of-scale hypothesis. We analyze the results here through the lens of these models.

Table B.1 confirms the well-known positive relationship between revenue and TFP in our data. The table shows the coefficients from regressing TFP on revenue with time fixed effects. The coefficient is around 0.20, and it is statistically significant at a 99% confidence level in all specifications, which vary in their TFP measure and in whether they include sector fixed effects.

Table B.2 regresses revenue on tariffs and the set of control variables described in the main text. The coefficient on output tariff is more mixed than in the TFP regressions. Tariff reductions are associated with an increase in firm revenue in the OLS specifications, and with a decrease in revenue in the IV specifications. For example, Columns (3) and (4) show the results for the subsample with only non-exporting firms. The coefficient in the OLS regression is -0.034 indicating that a 10 percent reduction in tariffs is associated with a 0.3 percent increase in revenue, while the coefficient on the IV, 0.0556, associates a 10 percent reduction in tariffs with a decrease in revenue of 0.5 percent.

A back-of-the-envelope calculation suggests that this effect of output tariffs on revenue is neither robust nor sufficiently large to support the economies-of-scale hypothesis. The elasticity of TFP with respect to revenue in Table B.1 is 0.2. Even if this relationship were entirely due to returns to scale, to explain the coefficient of TFP on tariffs of -0.06 (Column (5) of Table 1), one would need the coefficient of revenue on tariff to be -0.3 (=0.2/-0.06), ten times larger than the negative coefficient -0.034 in the OLS regression (Column (3) Table B.2). That is, to explain the effect of tariff cuts in increasing TFP in the data using a returns-to-scale mechanism, one would need tariff cuts (import competition) to substantially *increase* sales of domestic firms. The opposite is true in the data and in virtually any trade model.

For the downstream tariffs, the signs of the coefficients on downstream tariffs in Table 1 in

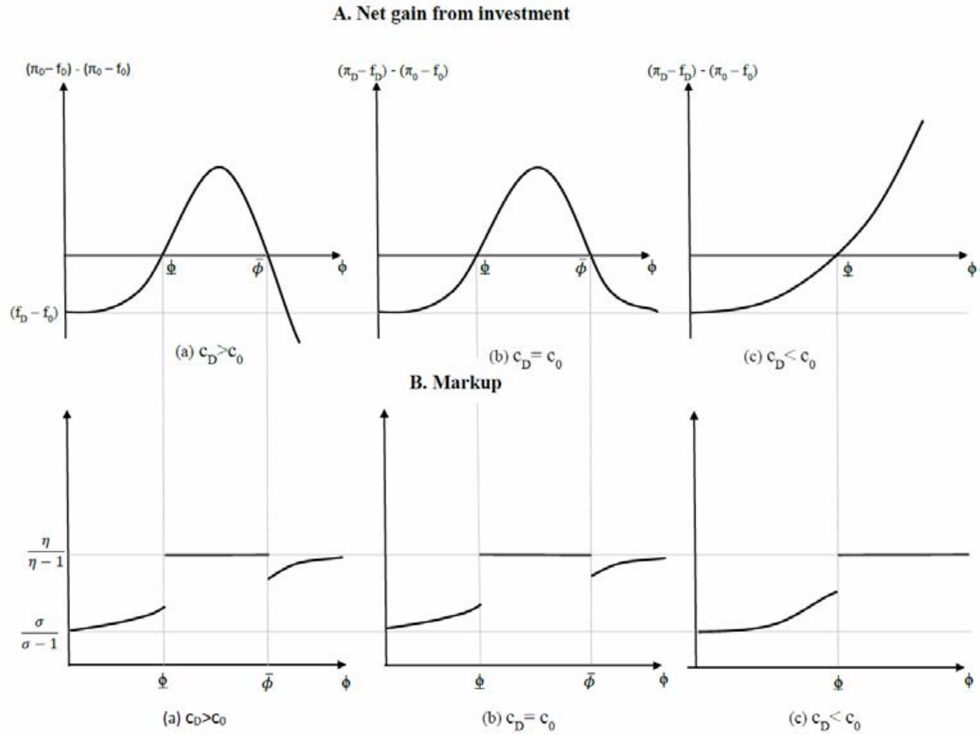
Table B.2: Basic Regressions of Revenue on Tariffs

The dependent variable is log of revenue

	All enterprises		Non-Exporters Only		All enterprises		Non-Exporters Only	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
output_tariff	-0.0275**	0.0549*	-0.0336***	0.0556*	-0.0182	0.0533	-0.0260*	0.0697**
	(0.0118)	(0.0309)	(0.0115)	(0.0306)	(0.0119)	(0.0344)	(0.0130)	(0.0337)
downstream_tariff	0.0411	0.534***	0.0116	0.383***	0.0814**	1.110***	0.0439	0.756***
	(0.0253)	(0.0728)	(0.0236)	(0.0865)	(0.0372)	(0.1180)	(0.0364)	(0.1390)
upstream_tariff	0.0142	-0.131	0.0129	-0.223*	-0.103	-0.678***	-0.122	-0.580***
	(0.0391)	(0.1100)	(0.0412)	(0.1160)	(0.0741)	(0.1830)	(0.0819)	(0.1850)
index_subsidy	0.0972***	0.0976***	0.0828***	0.0829***	0.0933***	0.0939***	0.0792***	0.0796***
	(0.0063)	(0.0029)	(0.0071)	(0.0036)	(0.0064)	(0.0029)	(0.0071)	(0.0036)
index_tax	0.0660***	0.0662***	0.0685***	0.0688***	0.0658***	0.0663***	0.0679***	0.0687***
	(0.0025)	(0.0018)	(0.0029)	(0.0021)	(0.0024)	(0.0018)	(0.0029)	(0.0021)
index_interest	-0.0995***	-0.0998***	-0.110***	-0.110***	-0.0966***	-0.0969***	-0.106***	-0.106***
	(0.0034)	(0.0022)	(0.0033)	(0.0026)	(0.0033)	(0.0022)	(0.0033)	(0.0025)
exportshare_sector	0.014	-0.375***	-0.139	-0.393***	0.471***	-0.216**	-0.129	-0.520***
	(0.0829)	(0.0545)	(0.0981)	(0.0672)	(0.1490)	(0.0895)	(0.1910)	(0.1070)
state_share	0.0422***	0.0428***	0.0391***	0.0394***	0.0433***	0.0422***	0.0402***	0.0397***
	(0.0097)	(0.0090)	(0.0106)	(0.0102)	(0.0097)	(0.0090)	(0.0109)	(0.0101)
Horizontal FDI	-0.0287	-0.0106	0.0292	0.0635	-0.1	-0.239***	-0.0147	-0.0984
	(0.1750)	(0.0543)	(0.1860)	(0.0596)	(0.2840)	(0.0642)	(0.3140)	(0.0758)
Downstream FDI	0.758*	-0.395**	0.828*	0.144	0.215	-3.035***	-0.184	-2.218***
	(0.4070)	(0.1880)	(0.4350)	(0.2160)	(1.0560)	(0.4540)	(1.0790)	(0.5320)
Upstream FDI	0.222**	0.433***	0.208**	0.416***	0.672***	0.501***	0.481**	0.457***
	(0.0972)	(0.0478)	(0.1030)	(0.0570)	(0.1960)	(0.0960)	(0.2350)	(0.1030)
Sector Fixed Effects	no	no	no	no	yes	yes	yes	yes
Observations	982,142	982,142	777,739	777,739	982,142	982,142	777,739	777,739

Standard errors are clustered. Tariffs and revenue are in logs. All specifications include fixed effects for the firm and time. IV estimates use initial 1998 tariffs and initial tariffs interacted with a WTO dummy as instruments. *** indicates $p < 0.01$, ** $p < 0.05$, and * indicates $p < 0.1$.

Figure C.1: Gains from investing and markups



the main text and Appendix Table B.2 are inconsistent with the economies-of-scale hypothesis. A reduction in downstream tariffs is associated with an increase in TFP and a decrease in sales. Only the coefficients on upstream tariffs are in line with the economies-of-scale hypothesis. A reduction in upstream tariff is associated with an increase in sales and in TFP.

In sum, the results on tariffs and revenues provide further evidence against the economies-of-scale hypothesis. In the OLS specifications for output tariffs, we find no evidence that tariff reductions are associated with sufficiently large increases in sales to rationalize the TFP results. In our preferred IV specifications, the data contradict the economies-of-scale hypothesis for both output and downstream tariffs. In both cases, tariff reductions are associated with an increase in TFP and a decrease in sales. This is clearly inconsistent with the hypothesis that investments in productivity are determined exclusively by economies of scale.

C Proofs of Model with Only Downstream Firms

Appendix C.1 presents the gains from investing when $c_D \leq c_0$, while the main text focuses on the case $c_D > c_0$. Appendix C.2 proves the positive predictions of the model, and Appendix C.3 proves the welfare results.

C.1 Gain from Investing and Markup in the General Case

Figure C.1 illustrates figure 2 in the paper for the cases where $c_D > c_0$ (as in the main text), $c_D = c_0$ and $c_D < c_0$. Note that the limit of $\pi_D - \pi_0$ is zero when ϕ tends to infinity when $c_D = c_0$. This result is proven below in the investment Proposition 2. In a cross-section, the case where $c_D < c_0$ is the same as Bustos (2011) where all firms above a threshold productivity invest. Over time, these models differ because import-competing tariffs always decreases the investment in Bustos, and it always increases the investment in the new model.

C.2 Positive Predictions: Exit, Investment, Trade

We prove Propositions 1 and 2, and discuss the issue of convexity of the set of investing firms.

Proposition 1: Exit. *There exists a unique $\tilde{\phi} > 0$ such that firms produce if and only if $\phi \geq \tilde{\phi}$. Cutoff $\tilde{\phi}$ is decreasing in $\overline{P}$, and increasing in costs c_D and c_0.*

Claim 1. *Cutoff $\tilde{\phi} > 0$ is unique for all firms* Suppose by contradiction that i firm with productivity ϕ_i enters and a firm j with $\phi_j > \phi_i$ does not enter. If firm i invests in differentiation, then trivially, firm j would make positive profits from entering and investing. Let firm j be the lowest productivity firm that does not enter and that has some firms with productivity lower than it enter. Consider the subgame perfect equilibrium where firm j enters and does not invest. If any of the subsequent firms remain in the market, then firm j must make positive profits in this subgame, since other firms have productivity lower than j. So, the entry of firm j must induce exit from all subsequent firms to exit. This is a contradiction because firm j's profits in this subgame equilibrium must be strictly higher than $\pi_i \geq 0$.

For the **properties of** $\tilde{\phi}$, it is sufficient to prove the properties of the cutoff $\tilde{\phi}$ for a given $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$. Profits π_0 and π_D are both strictly increasing in ϕ with limits $\lim_{\phi\to 0} \max\{\pi_D, \pi_0\} = 0$ and $\lim_{\phi\to\infty} \min\{\pi_D, \pi_0\} = \infty$. Then, $\tilde{\phi} \in \mathbb{R}_{++}$. The relationship between the cutoff and exogenous variables are an application of the Envelope Theorem to profits. Profits π_D and π_0 both increase in price index $\overline{P}$. If the lowest-productivity firm invests at threshold $\tilde{\phi}$, then its profit π_D is strictly decreasing in c_D. Otherwise, profit π_0 is strictly decreasing in c_0. ■

Proposition 2 Investment. *A. For all $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$, there exist cutoffs $\underline{\phi} > 0$ and $\overline{\phi} \geq \underline{\phi}$ such that the firm does not invest if $\phi < \underline{\phi}$ or $\phi > \overline{\phi}$). The upper limit $\overline{\phi}$ satisfies*

(i) $\overline{\phi} = \infty$ *if* $c_D < c_0$

(ii) $\overline{\phi} < \infty$ *if* $c_D \geq c_0$

B. *The set of investing firms is*

(iii) *increasing in* $\overline{P}$ *and* c_0

(iv) *decreasing in* P_{-i0} *and* c_D

Part B is a straightforward application of the envelope theorem to profits and hence we do not prove it. To prove part A, we take the limits of the gain from investing when ϕ tends to 0 or infinity, in claims 1 and 2.

Claim 1. Lower bound *There exists $\underline{\phi} > 0$ such that firms do not invest if $\underline{\phi} < \phi$.*

Proof. Profits π_0 and π_D go to zero as $\phi \to 0$, and so the gain from investing $\pi_D - \pi_0$ must also go to zero. Then, there exists a sufficiently small $\tilde{\phi}$ such that $(\pi_D - \pi_0) < f_D - f_0$ and hence no firm invests if $\phi < \tilde{\phi}$. Since at least some firm invests in the statement of the proposition, take $\underline{\phi}$ to be the infimum ϕ such that the firm invests and does not exit: $(\pi_D - \pi_0) \geq f_D - f_0$ and $\pi_D \geq f_D$.

Claim 2. Upper bound The following limit holds

$$\lim_{\phi\to\infty} (\pi_D - \pi_0) = \begin{cases} \infty & \text{if } c_D < c_0 \\ 0 & \text{if } c_D = c_0 \\ -\infty & \text{if } c_D > c_0. \end{cases}$$

For a non-differentiated firm, $\lim_{\phi\to\infty} s = 1$, $\lim_{\phi\to\infty} \epsilon = \eta$ and $\lim_{\phi\to\infty} P_0 = \frac{\eta c_0}{(\eta-1)\phi}$. We use these limits below,

$$\begin{aligned}
\lim_{\phi\to\infty} (\pi_D - \pi_0) &= \lim_{\phi\to\infty} \overline{P}^{\eta-1} \left[\frac{1}{\eta} \left(\frac{\eta c_D}{(\eta-1)\phi} \right)^{1-\eta} - \frac{P_0^{\sigma-\eta}}{\epsilon_0} \left(\frac{\epsilon_0 c_0}{(\epsilon_0 - 1)\phi} \right)^{1-\sigma} \right] \\
&= \overline{P}^{\eta-1} \left[\frac{1}{\eta} \left(\frac{\eta c_D}{(\eta-1)\phi} \right)^{1-\eta} - \frac{1}{\eta} \left(\frac{\eta c_0}{(\eta-1)\phi} \right)^{1-\eta} \right] \\
&= \overline{P}^{\eta-1} \frac{1}{\eta} \left(\frac{\eta}{(\eta-1)\phi} \right)^{1-\eta} \left[c_D^{1-\eta} - c_0^{1-\eta} \right]
\end{aligned}$$

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

$$\begin{aligned}
\left[c_D^{1-\eta} - c_0^{1-\eta} \right] &< 0 \qquad \text{if } c_D > c_0 \\
\left[c_D^{1-\eta} - c_0^{1-\eta} \right] &= 0 \qquad \text{if } c_D = c_0 \\
\left[c_D^{1-\eta} - c_0^{1-\eta} \right] &> 0 \qquad \text{if } c_D < c_0
\end{aligned}$$

■

Convexity I. *We find sufficient conditions for the set of investing firms to be convex for a given vector $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$.*

Step 1. Get $\frac{d\pi}{d\phi}$. The profit of a downstream firm is

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

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

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

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

Step 2. Get $\frac{d\epsilon}{d\phi}$. The elasticity of demand is implicitly defined through equation

$$\Psi \equiv (\sigma - \eta)s - \sigma + \epsilon = 0 \tag{C.2}$$

$$\text{where} \quad s = \frac{\left(\frac{\epsilon}{(\epsilon-1)\phi}\right)^{1-\sigma}}{P_{-i0}^{1-\sigma} + \left(\frac{\epsilon}{(\epsilon-1)\phi}\right)^{1-\sigma}} \tag{C.3}$$

Taking derivatives,

$$\begin{aligned}
\phi\Psi_\phi &= (\sigma - \eta)(\sigma - 1)(1 - s)s \\
\epsilon\Psi_\epsilon &= \epsilon + (\sigma - \eta)(\sigma - 1)(1 - s)s/(\epsilon - 1)
\end{aligned}$$

where we use the standard notation $\Psi_x = \partial\Psi/(\partial x)$ for any variable x. By the Implicit Function Theorem,

$$\frac{\phi d\epsilon}{\epsilon d\phi} = -\frac{\phi\Psi_\phi}{\epsilon\Psi_\epsilon} = -\frac{(\sigma - \eta)(\sigma - 1)(1 - s)s}{\epsilon + (\sigma - \eta)(\sigma - 1)(1 - s)s/(\epsilon - 1)} \tag{C.4}$$

Step 3: $s \leq 1/2$ **case.** Define the net gain from investing as $G(\phi) = (\pi_D(\phi) - \pi_0(\phi))$. We show that G has a unique maximum.[1] That is, for all ϕ satisfying the first order conditions, the second order conditions hold strictly. Using the derivatives in (C.1),

$$\begin{aligned}
G'(\phi) &= \frac{1}{\phi}\left[(\eta - 1)\pi_D - (\epsilon - 1)\pi_0\right] \\
G''(\phi) &= -\frac{1}{\phi^2}\left[(\eta - 1)\pi_D - (\epsilon - 1)\pi_0\right] + \frac{1}{\phi^2}\left[(\eta - 1)^2\pi_D - (\epsilon - 1)^2\pi_0\right] - \frac{\pi_0}{\phi}\frac{d\epsilon}{d\phi}
\end{aligned}$$

[1] It suffices to prove that there does not exist a local minimum for the gain from investing G. If there existed $\phi' < \phi'' < \phi'''$ such that the firm invested at ϕ' and ϕ''' but not at ϕ'' then $G(\phi'') \leq \min\{G(\phi'), G(\phi''')\}$ and there would be a local minimum in $[\phi', \phi''']$.

Evaluating $G''(\phi)$ where $G'(\phi^*) = 0$ and using equation (C.4), we have

$$\begin{aligned}
G''(\phi^*) &= \frac{1}{\phi^2}\left[(\eta-1)^2\pi_D - (\epsilon-1)^2\pi_0\right] - \frac{1}{\phi}\pi_0\frac{d\epsilon}{d\phi} \\
&= \frac{\pi_0}{\phi^2}\left[(\eta-1)(\epsilon-1) - (\epsilon-1)^2\right] + \frac{\pi_0}{\phi^2}\left(\frac{\epsilon(\sigma-\eta)(\sigma-1)(1-s)s}{\epsilon+(\sigma-\eta)(\sigma-1)(1-s)s/(\epsilon-1)}\right) \\
&= \frac{\pi_0}{\phi^2}(\sigma-\eta)(1-s)\left[-(\epsilon-1) + \frac{\epsilon(\sigma-1)s}{\epsilon+(\epsilon-\eta)(\sigma-1)s/(\epsilon-1)}\right]
\end{aligned}$$

where the second line uses equation (C.4) and the third line uses $(\epsilon-\eta) = (\sigma-\eta)(1-s)$ from rearranging equation (C.2). Since the term out of the brackets is positive, to prove $G'' < 0$, we must show

$$\begin{aligned}
&\epsilon - 1 > \frac{\epsilon(\sigma-1)s}{\epsilon+(\epsilon-\eta)(\sigma-1)s/(\epsilon-1)} \\
\Leftrightarrow\quad &(\epsilon-\eta)(\sigma-1)s + \epsilon(\epsilon-1) - \epsilon(\sigma-1)s > 0 \\
\Leftrightarrow\quad &\epsilon(\epsilon-1) - \eta(\sigma-1)s > 0 \\
\Leftrightarrow\quad &\frac{\epsilon(\epsilon-1)}{\sigma-\epsilon} > \frac{\eta(\sigma-1)}{\sigma-\eta}
\end{aligned} \tag{C.5}$$

The inequality does not hold everywhere since it does not hold when $s = 1$ and $\epsilon = \eta$. But the right-hand-side is increasing in ϵ and decreasing in s. So, if we show that the inequality holds for $s = 1/2$, then it holds for all $s \leq 1/2$. When $s = 1/2$, $\epsilon = (\sigma+\eta)/2$ and equation (C.5) becomes

$$\begin{aligned}
&\frac{(\sigma+\eta)(\sigma+\eta-2)}{2(\sigma-\eta)} > \frac{\eta(\sigma-1)}{\sigma-\eta} \\
\Leftrightarrow\quad &(\sigma+\eta)^2 - 2\sigma - 2\eta > 2\eta\sigma - 2\eta \\
\Leftrightarrow\quad &\sigma^2 + \eta^2 + 2\eta\sigma - 2\sigma > 2\eta\sigma \\
\Leftrightarrow\quad &(\sigma-\eta)^2 + 2\eta\sigma - 2\sigma > 0 \\
\Leftrightarrow\quad &(\sigma-\eta)^2 + 2\sigma(\eta-1) > 0
\end{aligned}$$

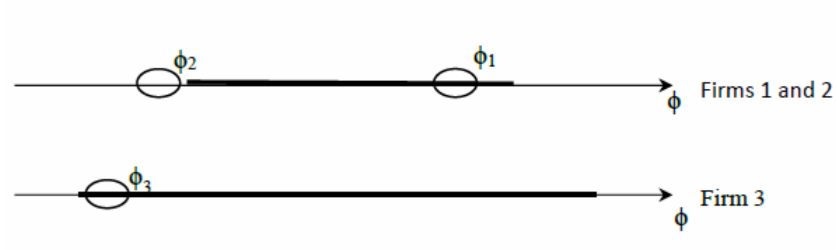
which always holds since $\eta > 1$. ■

Step 4: $s > 1/2$ case. From the above proof, the second order conditions may not hold when $s > 1/2$. So, we ask here whether the first order conditions may hold. If they never did, then convexity would follow. Using the expressions for profits, we can rewrite these conditions as:

$$\begin{aligned}
(\eta-1)\pi_D &= (\epsilon-1)\pi_0 \\
\frac{\eta-1}{\eta}\left(\frac{\eta c_D}{(\eta-1)\phi}\right)^{1-\eta} &= \frac{\epsilon-1}{\epsilon}P_0^{\sigma-\eta}\left(\frac{\eta c_0}{(\eta-1)\phi}\right)^{1-\sigma}. \\
\equiv \quad s &= \left(\frac{\epsilon(\eta-1)}{(\epsilon-1)\eta}\right)\left(\frac{\eta c_D}{(\eta-1)\phi}\right)^{1-\eta} P_0^{\eta-1}
\end{aligned}$$

The first term is always smaller than one. The second term is the ratio of sales of the firm if it

Figure C.2: Set of productivities ϕ where investment is profitable, given $P_{-10} = P_{-20} > P_{-30}$



becomes differentiated to the sales of all non-differentiated firms if the firm is does not invest. So, a sufficient condition for the set of investing firms to be convex is for this ratio of sales to always be less than 1/2. Alternatively, we can use $P_0 < \epsilon c_0/[(1-\epsilon)\phi]$. Then,

$$s < \left(\frac{\epsilon(\eta-1)}{(\epsilon-1)\eta}\right)^{\eta}\left(\frac{c_0}{c_D}\right)^{\eta-1} < \left(\frac{c_0}{c_D}\right)^{\eta-1}$$

So that a sufficient condition on the problem's exogenous parameters is for the marginal cost of the differentiated good to be sufficiently high: $(c_0/c_D)^{\eta-1} < 1/2$.

To summarize, for a given $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$, the set of firms investing as a function of ϕ is convex if one of the following conditions hold: (i) The firm's market share in the non-differentiated nest is less than 0.5, (ii) the ratio of the firm's sales if it becomes differentiated relative to its sales if it is not differentiated is less than 0.5, or (iii) $(c_0/c_D)^{\eta-1} < 1/2$.

Convexity II. *We show that the set of firms investing is not necessarily convex in a given equilibrium because firms face different levels of competition in the non-differentiated nest* P_{-i0}. The conditions above are sufficient for the set of firms investing to be convex in ϕ for a given $\left(P_{-i0}, \overline{P}, c_0, c_D\right)$. While $\left(\overline{P}, c_0, c_D\right)$ is common for all firms, P_{-i0} is not. We sketch an example where the equilibrium set of investing firms is not necessarily convex. Consider an economy with Foreign competition and three domestic firms with productivity parameters $\phi_1 > \phi_2 > \phi_3$. Let $c_D = c_0$ so that the set of investing firms is a bounded interval $(\underline{\phi}, \overline{\phi})$ for any given P_{-i0}. We claim that for some parameter values, it is possible to construct an equilibrium with strategies {invest, not invest, invest}. Suppose that in the subgame where firm 1 does not invest, then the two other firms invest. Then, the level of competition faced by the three firms in the non-differentiated nest is $P_{-10} = P_{-20} > P_{-30}$.[2] Then, the set of productivity ϕ that makes the investment profitable is illustrated in Figure C.2 in bold. The set is larger for firm 3 because $P_{-10} = P_{-20} > P_{-30}$, and so it is possible to judiciously pick productivity levels in the regions indicated with an oval such that the proposed equilibrium holds.

[2] In this example, $P_{0F} = P_{-10} = P_{-20}$.

C.3 Welfare

We use the following notation. Given a set of discrete choices, set $\mathcal{D}$ is the set of differentiated firms and $\mathcal{O}$ is the set of non-differentiated firms as before. The markup of firm i is denoted with μ_{0i} if the firm is non-differentiated and with $\mu_D = \eta/(\eta-1)$ if the firm is differentiated.

C.3.1 Lemma 4: Productivity and labor allocation

Lemma *For any two non-differentiated firms, constrained planner 1 allocates relatively more labor to the more productive firm compared to the market. Constrained planner 1 also allocates more labor to set $\mathcal{D}$ relative to $\mathcal{O}$.*

Planner's problem. The superscript W refers to the planner's choices. Constrained planner 1 cannot change sets $\mathcal{O}$ and $\mathcal{D}$. But after firms make their discrete choices, he can unexpectedly change labor allocations. His problem is to choose quantities q_i maximize

$$\max U = \left[(Q_0^W)^{\frac{\eta-1}{\eta}} + \sum_{i\in\mathcal{D}} q_i^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

$$\text{subject to} \quad Q_0^W = \left(\sum_{i\in\mathcal{O}} q_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$L = \sum_{i\in\mathcal{O}} \left(\frac{c_0}{\phi} q_i \right) + \sum_{i\in\mathcal{D}} \left(\frac{c_D}{\phi} q_i \right). \tag{C.6}$$

We denote utility here with U rather than Q because U is only the contribution to overall utility of the firms modeled, not including exogenous nests. The first order conditions with respect to quantities imply that a firm with productivity ϕ has quantities

$$q_0^W = \lambda^{-\sigma} \left(\frac{c_0}{\phi} \right)^{-\sigma} Q^{\sigma/\eta} (Q_0^W)^{(\eta-\sigma)/\eta}$$

$$q_D^W = \lambda^{-\eta} \left(\frac{c_D}{\phi} \right)^{-\eta} Q$$

where λ is the Lagrange multiplier for constraint (C.6) and we denote the firm's quantities with q_0^W if its variety is not differentiated and q_D^W if it is differentiated. Substituting q_0^W in the definition of Q_0^W and rearranging, we get

$$Q_0^W = (\lambda C_0)^{-\eta} Q$$

$$\text{where} \quad C_0 = c_0 \left(\sum_{i\in\mathcal{O}} \phi_i^{\sigma-1} \right)^{\frac{1}{1-\sigma}}. \tag{C.7}$$

Substituting it back into quantities of varieties,

$$q_0^W = \lambda^{-\eta} Q C_0^{\sigma-\eta} \left(\frac{c_0}{\phi}\right)^{-\sigma}$$

Similarly to C_0, we define the aggregate cost of the differentiated goods $\mathcal{D}$:

$$C_D = c_D \left(\sum_{i\in\mathcal{D}} \phi_i^{\eta-1}\right)^{\frac{1}{1-\eta}}.$$

The planner's allocation of labor for production is then

$$\begin{aligned} L_0^W &= \lambda^{-\eta} Q C_0^{1-\eta} \\ L_D^W &= \lambda^{-\eta} Q C_D^{1-\eta} \end{aligned} \tag{C.8}$$

Market. Market quantities of individual varieties are:

$$\begin{aligned} q_0 &= Q\overline{P}^{\eta} P_0^{\sigma-\eta} (\mu_{0i} c_0/\phi)^{-\sigma} \\ q_D &= Q\overline{P}^{\eta} (\mu_D c_D/\phi)^{-\eta} \end{aligned}$$

Aggregating over varieties we get the labor used for production of the non-differentiated varieties L_0 and of differentiated varieties L_D:

$$\begin{aligned} L_0 &= \sum_{i\in\mathcal{O}} q_{0i} \frac{c_0}{\phi_i} = Q\overline{P}^{\eta} P_0^{\sigma-\eta} \sum_{i\in\mathcal{O}} (\mu_{0i})^{-\sigma} (c_0/\phi_i)^{1-\sigma} \\ L_D &= \sum_{i\in\mathcal{O}} q_{Di} \frac{c_D}{\phi_i} = Q\overline{P}^{\eta} \mu_D^{-\eta} \sum_{i\in\mathcal{O}} (c_D/\phi_i)^{1-\eta} = Q\overline{P}^{\eta} \mu_D^{-\eta} C_D^{1-\eta} \end{aligned} \tag{C.9}$$

To compare it to the planner's allocations, L_0^W and L_D^W, note that since $\mu_D > \mu_{0i}$ for all i, the following inequalities hold

$$\begin{aligned} L_0 &= Q\overline{P}^{\eta} P_0^{\sigma-\eta} \left(\sum_{i\in\mathcal{O}} (\mu_{0i})^{-\sigma} (c_0/\phi_i)^{1-\sigma}\right) \\ &= Q\overline{P}^{\eta} \mu_D^{-\eta} \left[\sum_{i\in\mathcal{O}} \frac{\mu_{0i}}{\mu_D} \left(\frac{\mu_{0i}}{\mu_D}\right)^{-\sigma} (c_0/\phi_i)^{1-\sigma}\right]^{\frac{\sigma-\eta}{1-\sigma}} \left[\sum_{i\in\mathcal{O}} \left(\frac{\mu_{0i}}{\mu_D}\right)^{-\sigma} (c_0/\phi_i)^{1-\sigma}\right] \\ &> Q\overline{P}^{\eta} \mu_D^{-\eta} \left[\sum_{i\in\mathcal{O}} \left(\frac{\mu_{0i}}{\mu_D}\right)^{-\sigma} (c_0/\phi_i)^{1-\sigma}\right]^{\frac{1-\eta}{1-\sigma}} \\ &> Q\overline{P}^{\eta} \mu_D^{-\eta} C_0^{1-\eta} \end{aligned} \tag{C.10}$$

Taking the ratio of expressions (C.9) and (C.10) and comparing it to equations (C.8), we have:

$$\frac{L_0}{L_D} > \frac{L_0^W}{L_D^W}$$

Given the same sets $\mathcal{O}$ and $\mathcal{D}$, the market allocates relatively more labor to the non-differentiated nest compared to the planner. The intuition for this result is the same as the allocation of labor across varieties within the non-differentiated nest. Compared to the planner, the market allocates relatively more labor to the nest with lower markups.

C.3.2 Welfare and Discrete Choices

We now turn to the discrete choices: To exit, produce, and invest. As in the main text, Assumption A2 puts structure into the gains from allocating labor for the fixed costs to sectors not modeled. Denote with C the aggregate marginal cost of labor in the economy. For example, if marginal cost is constant in other sectors, then $C = L/Q$ where L is the labor allocated for production and Q is aggregate utility. Define the average markup in the economy as $\overline{\mu} = \overline{P}/C$, price over marginal cost. We uphold the following assumption:

A2. Assumption *The market equilibrium satisfies* $\overline{\mu} < \mu_D$ *and* $\overline{\mu} \geq \mu_{0i}$ *for all* i *in the non-differentiated nest* $\mathcal{O}$.

Constrained planner 2 can choose sets $\mathcal{O}$ and $\mathcal{D}$, but once these sets are chosen, firms are free to choose prices and quantities clear the market. Denote with $v(\mathbf{p}, w)$ the indirect utility of the consumer when the vector of prices is $\mathbf{p}$ and consumer income is w. Denote with $(\mathbf{p}_{-i}, p')$ the vector of prices where the i^{th} element is changed to p' and all other elements are maintained at their original $\mathbf{p}$ prices. Then, the utility of variety i to the planner is

$$u_i = v(\mathbf{p}, 1) - v((\mathbf{p}_{-i}, \infty), 1) - f_i/C \tag{C.11}$$

where $\mathbf{p}$ is the equilibrium prices and income is set to one because it is the numeraire. That is, the utility of variety i is the change in indirect utility to the consumer when the price of i is raised from infinity to its equilibrium level and the fixed cost is reallocated from the production of other goods to variety i where $f_i = f_0$ if the firm is non-differentiated and $f_i = f_D$ if it is differentiated.

By Roy's identity,

$$q_i(\mathbf{p}, w) = -\frac{v_i(\mathbf{p}, 1)}{v_w(\mathbf{p}, 1)}$$

where $q_i = x_i/p_i$ is demand function, v_i is the partial derivative of v with respect to p_i and v_w is the partial derivative with respect to consumer income: $v_w(\mathbf{p}, w) = \overline{P}^{-1}$. Applying the fundamental theorem of calculus to equation (C.12) and using Roy's identity, we have

$$\begin{aligned} u_i &= -\overline{P}^{-1}\int_{p_i}^{\infty} v_i((\mathbf{p}_{-i}, p'), 1)dp - f/C \\ &= \overline{P}^{-1}\int_{p_i}^{\infty} q_i((\mathbf{p}_{-i}, p'), 1)dp' - f/C \end{aligned} \tag{C.12}$$

For differentiated firms whose demand has a constant elasticity of demand, we write

$$q_i((\mathbf{p}_{-i}, p'), 1) = A_i(p')^{-\eta}. \tag{C.13}$$

Constant A_i is set by the condition that for equilibrium price $p_i = \mu_D c_D/\phi_i$, demand is

$$q_{iD}(\mathbf{p}, 1) = QP^{\eta}(p_i)^{-\eta}$$

where $Q = 1/\overline{P}$ is the consumer's total utility. Substituting ($C.13$) into u_i, we have:

$$\begin{aligned} u_i &= \overline{P}^{-1}\int_{p_i}^{\infty} q_i((\mathbf{p}_{-i}, p'), 1)dp' - f/C \\ &= \overline{P}^{-1} A_i \frac{1}{\eta - 1}(p')^{1-\eta}|_{p'=p_i}^{\infty} - f/C \\ &= \frac{\overline{P}^{-1}}{\eta - 1} QP^{\eta}(p_i)^{1-\eta} - f/C \\ &= C^{-1}\left[\left(\frac{\mu_D}{\overline{\mu}}\right)\frac{QP^{\eta}}{\eta}(p_i)^{1-\eta} - f\right] \\ &> C^{-1}\left[\frac{QP^{\eta}}{\eta}(p_i)^{1-\eta} - f\right] = C^{-1}\pi_D \end{aligned} \tag{C.14}$$

where the last line comes from Assumption A2.

For non-differentiated varieties, demand at equilibrium prices is

$$q_{i0}(\mathbf{p}, 1) = QP^{\eta}P_0^{\sigma-\eta}(p_i)^{-\sigma}$$

where the equilibrium price for non-differentiated varieties is $p_i = \epsilon_i c_0/(\phi_i(\epsilon_i - 1)$, and ϵ_i is the elasticity of demand for variety i at $\mathbf{p}$. By Assumption A2, non-differentiated varieties do not have a monopoly of nets $\mathcal{O}$. Then the elasticity of demand is strictly increasing in the interval

$p' \in [p_i, \infty)$, and the following inequality holds:

$$\begin{aligned}
u_i &= \overline{P}^{-1} \int_{p_i}^{\infty} q_i((\mathbf{p}_{-i}, p'), 1) dp' - f/C \\
&< \overline{P}^{-1} \frac{1}{\epsilon_i - 1} q_i(\mathbf{p}, 1) p_i - f/C \\
&= C^{-1} \left[\frac{Q P^{\eta} P_0^{\sigma-\eta}}{\epsilon_i - 1} (p_i)^{1-\sigma} - f \right] \\
&= C^{-1} \left[\left(\frac{\mu_{0i}}{\overline{\mu}} \right) \frac{Q P^{\eta} P_0^{\sigma-\eta}}{\epsilon_i} (p_i)^{1-\sigma} - f \right] \\
&< C^{-1} \left[\frac{Q P^{\eta}}{\epsilon_i} (p_i)^{1-\eta} - f \right] = C^{-1} \pi_0
\end{aligned} \tag{C.15}$$

The expression in the second line would be the utility from variety i if its elasticity remained at ϵ_i as its price increased. So, the inequality holds because demand falls strictly below this constant elasticity case for all $p' \in [p_i, \infty)$. The last inequality comes from Assumption A2. Compared to the market, the planner's valuation is multiplied by C^{-1} simply to convert units from money to labor. More relevant is that inequalities (C.14) and (C.15) implies that compared to the limited planner, the market features too much entry of unproductive, non-differentiated varieties in $\mathcal{O}$ and too little investment in differentiation $\mathcal{D}$. Recall that given sets $\mathcal{O}$ and $\mathcal{D}$, the planner reallocates production from less productive to more productive firms within $\mathcal{O}$, and from set $\mathcal{O}$ to set $\mathcal{D}$. So, the discrete choice results that the market features too much entry of unproductive, non-differentiated varieties in $\mathcal{O}$ and too little investment in non-differentiation $\mathcal{D}$ holds also for an unconstrained planner who can choose sets $\mathcal{O}$ and $\mathcal{D}$ as well as labor allocations.

A corollary to these results is that investment induced by international trade is welfare enhancing. That is, compared to a scenario where firms are forced not to change their discrete choices, the exit of the least productive firms from nest $\mathcal{O}$ and the increase in investment is always welfare enhancing. Hence, this completes the proof of the propositions and lemmas in the main text.

Lemma *Consider a planner who chooses sets $\mathcal{O}$ and $\mathcal{D}$ but cannot choose prices and labor allocations given these sets. Relative to this planner, the market features too much entry of unproductive, non-differentiated varieties in $\mathcal{O}$ and too little investment in non-differentiation $\mathcal{D}$.*

Recall that from Lemma 4, given sets $\mathcal{O}$ and $\mathcal{D}$, the planner reallocates production from less productive to more productive firms within $\mathcal{O}$, and from set $\mathcal{O}$ to set $\mathcal{D}$. So, the results in the Lemma above hold for an unconstrained planner as stated in Proposition 5 in the main text.

D Model with Large Upstream Firms

We present here a version of the model where upstream firms internalize their effect on sales downstream and on input cost c_0.

Non-differentiated upstream firms The input cost of non-differentiated final goods is defined as in the main text,

$$c_0 = \left[(P_{0M})^{1-\eta_M} + (P_M)^{1-\eta_M}\right]^{\frac{1}{1-\eta_M}} \tag{D.1}$$

$$\text{where} \quad P_{0M} = \left[\sum_{i\in\mathcal{O}_M} (p_i)^{1-\sigma_M}\right]^{\frac{1}{1-\sigma_M}},$$

$\mathcal{O}_M$ is the set of non-differentiated upstream varieties, p_i is the price of variety i, P_{0M} is the price index of non-differentiated inputs, and P_M is the price index of all other inputs—potentially including labor, capital and materials from other upstream sectors. As in the downstream sector, we take P_M to be exogenous, while price index P_{0M} and set $\mathcal{O}_M$ are endogenous. Assume $\sigma_M > \eta_M$.

Spending on a non-differentiated upstream variety with price p is

$$x_M(p) = p^{1-\sigma_M}(P_{0M})^{\sigma_M-\eta_M} c_0^{\eta_M-1} X_{0M} \tag{D.2}$$

where X_0^M is total spending on non-differentiated inputs:

$$X_{0M} = \overline{P}^{\eta-1} P_0^{\sigma-\eta} c_0^{1-\sigma} \sum_{i\in\mathcal{O}_H} \left(\frac{\epsilon_i}{(\epsilon_i-1)}\right)^{-\sigma} \phi_i^{\sigma-1}$$

where $\mathcal{O}_H$ is the set of non-differentiated domestic final goods. An upstream firm with productivity ϕ_M has marginal cost $1/\phi_M$. Substituting X_{0M} into equation (D.2), its profit is

$$\pi_{0M} = \max_p E P_0^{\sigma-\eta} c_0^{\eta_M-\sigma} P_{0M}^{\sigma_M-\eta_M} p^{-\sigma_M}(p - 1/\phi_M) \tag{D.3}$$

where p is the price. With a finite set of varieties $\mathcal{O}_M$, the firm internalizes its effect on price indices P_{0M}, c_0 and P_0. The term

$$E = \overline{P}^{\eta-1} \sum_{i\in\mathcal{O}_H} \left(\frac{\epsilon_i - 1}{\epsilon_i}\right)^{\sigma} \phi_i^{\sigma-1}$$

is a market size effect. For simplicity, we assume that upstream firm takes the markup of downstream firms as exogenous, i.e., E as exogenous.[3]

We rewrite price index

$$P_0 = \left[P_{0H}^{1-\sigma} + P_{0F}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

$$\text{where} \quad P_{0H} = c_0 \sum_{i\in\mathcal{O}_H} \left(\frac{\epsilon_i}{(\epsilon_i-1)\phi_i}\right)^{1-\sigma},$$

P_{0F} are the exogenous foreign price index. Taking first order conditions on profit (D.3), the optimal

[3] Our main result below is that input suppliers' response to pro-competitive effect of import competition downstream is small. This result is strengthened if we relax this simplifying assumption. Input suppliers' price response would be even smaller if downstream firms did not fully pass-through input price reductions to consumers.

markup of the upstream firm is $\epsilon_M/(\epsilon_M - 1)$ where ϵ_M is the endogenous elasticity of demand:

$$\epsilon_M = \sigma_M(1 - s_M) + \eta_M s_M(1 - S_{0M}) + s_M S_{0M} \left[\sigma(1 - S_{0H}) + \eta S_{0H}\right] \tag{D.4}$$

where $s_M = (p/P_{0M})^{1-\sigma}$ is the market share of the firm in nest $\mathcal{O}_M$, $S_{0M} = (P_{0M}/c_0)^{1-\rho}$ is the share of nest $\mathcal{O}_M$ in the cost of non-differentiated downstream firms, and $S_{0H} = (P_{0H}/P_0)^{1-\sigma}$ is the domestic market share in non-differentiated downstream sales.

The firm's endogenous elasticity of demand ϵ_M is a weighted average of four elasticities: σ_M, η_M, σ, and η. The first two terms capture competition between inputs. If nest $\mathcal{O}_M$ had measure zero, then $S_{0M} = 0$ and the expression would reduce to the expression in the main text, where c_0 is exogenous. The last term captures competition downstream. The share of the upstream firm in the total cost of all non-differentiated domestic downstream firms is $s_M S_{0M}$. If this share is large, the firm internalizes the effect of its prices on the sales of downstream domestic firms, firms which compete with foreigners with an elasticity σ and with other nests with elasticity η.

Differentiated upstream firms The problem of differentiated upstream firms is defined exactly as in the main text. An upstream differentiated firm charges markup $\frac{\eta_M}{\eta_M - 1}$ and gets profits

$$\pi_{DM} = (\phi_M)^{\eta_M - 1} X_{DM}. \tag{D.5}$$

where ϕ_M is the firm's productivity, and X_{DM} is an exogenous market size effect. If $\eta_M \leq \eta$ the elasticity of demand of differentiated firms is always smaller than the endogenous elasticity ϵ_M in equation (D.4).

Equilibrium with intermediate inputs Price P_{0F} and productivity of all firms are exogenous and known. Timing is as follows. (i) In order of productivity, all upstream firms make their discrete choices. (ii) In order of productivity, all downstream firms make their discrete choices. (iii) Upstream firms simultaneously set prices. (iv) Downstream firms simultaneously set prices. (v) Markets clear.

The key distinction in prices relative to the main text is that upstream firms set prices before downstream firms. Then, input suppliers anticipate that a decrease in their prices will be passed through in stage (iv) and induce larger sales in stage (v). The problem of downstream firms is unchanged since they still take input costs as given.

Proposition: Import Competition for Downstream and Upstream Firms *A sufficiently large decrease in import tariffs increases the exit of upstream firms. Among surviving upstream firms, it increases investment in differentiation. If $\eta_M \leq \eta$, the markup increases for firms that invest in differentiation.*

The proposition is the same as before, except that now, non-differentiated upstream firms may decrease their prices in response to competition downstream because a large input provider internalizes the effect of its price on sales downstream. We argue next that this effect is generally small.

For easier reference, we repeat the equations with the elasticity of demand of downstream and upstream firms:

$$\epsilon = \sigma(1-s) + \eta s, \tag{D.6}$$

$$\epsilon_M = \sigma_M(1-s_M) + \eta_M s_M(1-S_{0M}) + s_M S_{0M}\left[\sigma(1-S_{0H}) + \eta S_{0H}\right]. \tag{D.7}$$

Taking the partial derivative of these equations with respect to P_{0F}, we have

$$\frac{\partial \epsilon}{\partial P_{0F}} = \frac{s}{S_{0H}}(\sigma-\eta)\left(-\frac{\partial S_{0H}}{\partial P_{0F}}\right),$$
$$\frac{\partial \epsilon_M}{\partial P_{0F}} = s_M S_{0M}(\sigma-\eta)\left(-\frac{\partial S_{0H}}{\partial P_{0F}}\right).$$

Rearranging and taking the average over all non-differentiated firms, we have

$$\overline{\frac{\partial \epsilon_M}{\partial P_{0F}}} = S_{0M}\left(\frac{|\mathcal{O}_H|}{|\mathcal{O}_M|}\right)\overline{\frac{\partial \epsilon}{\partial P_{0F}}} \tag{D.8}$$

where the over line indicates the average and $|\mathcal{O}|$ indicates the number of firms in set $\mathcal{O}$. The sign of $\partial\epsilon_M/\partial P_{0F}$ and $\partial\epsilon/\partial P_{0F}$ is the same: Tariff reductions decreases the markup of downstream firms directly competing with imports, as well as the markups of their large input suppliers that internalize these pro-competitive effects. But the magnitude of this effect is much smaller for upstream firms since $S_{0M} \in (0,1)$ is a market share.

Moreover, this partial equilibrium effect may be overturned by general equilibrium effects discussed in the main text. To the extent that the decrease in tariffs leads some upstream firms to exit or invest, the market share s_M increases. Hence, the markup of upstream firms in equation (D.7) also increases (ϵ_M decreases). In sum, the more general model presented in this Appendix cannot overturn the prediction of the model that the effect of import competition downstream on TFPR is larger for input suppliers than for firms directly competing with imports.

E Extensions of the Theory

We discuss short extensions of the model and robustness of the theoretical results. For simplicity, these extensions apply to the baseline model without input suppliers. Appendix E.1 presents two extensions to the partial equilibrium model. These extensions are described only in words because the mathematical proofs remain unchanged. In Appendices E.2 and E.3, we study the model in general equilibrium. In Appendix E.2, we revisit all predictions of the model in a symmetric two-country model with heterogeneous firms. Appendix E.3 derives gravity-type equations in a model with multiple nests and ex ante homogeneous goods. Like in the partial equilibrium model in the main text, international trade pushes firms toward nests where the elasticity of demand is low (more differentiated) and nests that are preferred by the domestic consumer.

E.1 Extensions of Partial Equilibrium Model

Increasing cost of investing. None of the theoretical results depend on the assumption that fixed costs are the same across firms. They hold in the more realistic scenario where the fixed cost of differentiating is increasing in the number of differentiated goods. That is, as more and more firms become differentiated, it becomes increasingly difficult for a firm to find its own market niche, i.e., its own nest in the model.[4]

Imitation and heterogeneous elasticity σ. Suppose that once a new nest has been created, other firms may enter the new nest with their own variety at a fixed cost lower than f_D. If international trade cannot eliminate the existence of nests (once market opportunities are discovered they cannot be forgotten), then it will always push firms away from the non-differentiated nest, as in Proposition 2. The markup of firms that remain in the non-differentiated nest always decreases with import competition. But now, the markup of the firms that invest may also decrease. The new markup depends on market shares and on the elasticity of substitution σ in the new nest. Since Proposition 2 already highlights the ambiguous effect of trade on the markup of import-competing firms, no positive prediction is lost.

On welfare, recall that Proposition 3 establishes that the social benefit of a new nest is always greater than the innovator's profit. This statement becomes stronger if an imitator steals some of the original innovator's profits. So, if imitation prevents innovation, then a planner would always prefer to ban imitation. Otherwise, if imitation does not change the innovator's discrete choice, then whether or not the planner prefers to ban imitation depends on market shares and the elasticity of substitution in the new nest with respect to the non-differentiated nest. In sum, the key theoretical results are robust to the presence of imitators and to nests with varying elasticities: International trade pushes firms toward newer nests and the creation of new nests is welfare increasing.

E.2 Two-Country General Equilibrium Model

We revisit the theoretical results a general equilibrium model with two symmetric countries, Home and Foreign. The population in each country is normalized to one. There is a continuum of sectors also with measure one. Wage is the numeraire. A continuum of entrepreneurs can pay a fixed cost to enter a sector. The fixed cost of entry is sufficiently large so that each sector will have only a finite number of firms. Upon entry, each firm draws its productivity from a common distribution with a finite support. Each sector j has two types of nests: A less differentiated nest $\mathcal{O}_j$, and differentiated nests. Only the differentiated nest is tradable. There is an iceberg trade cost $d > 1$: To deliver one unit of a good in the foreign country, d units of the good must be shipped from home. The main text made predictions about firms that did not export and were shocked only with

[4] If fixed costs vary across firms, depending on the vector of firm productivity, the planner will gain from reallocating the lower fixed costs from the more productive to the less productive firms if it leads to more investment. This point that it may be more difficult to find heterogeneous varieties when the mass of existing varieties increases may hold also in standard trade models where free entry is always modeled as a constant cost.

import competition. We capture these firms by assuming that a fraction β of firms cannot export. Firms only find out whether they can export or not after entry.

Demand and technologies are described in the main text, Sections 3.1.1 and 3.1.2. Spending is one because the wage and measure of population are one. The equilibrium game is simultaneously played in all sectors. Timing of the game is as follows. (i) Entrepreneurs enter (ii) All entrepreneurs observe their productivity and whether the firm can (potentially) export or not. (iii) In decreasing order of productivity, firms decide to exit, to produce a non-differentiated variety or a differentiated variety. (iv) All firms simultaneously set prices. Exporters set one price for each country.

We again consider the subgame perfect equilibrium. We describe the equilibrium from Home's perspective. Given symmetry over sectors and countries, and the timing above, the equilibrium number of entrepreneurs is as follows. A share $\alpha \in [0,1)$ of sectors have $F_1 \in \mathbb{Z}_+$ potentially active firms and a share $(1-\alpha)$ have F_1+1 firms. The overall price index $\overline{P}$ below is such that the expected profit of an entrepreneur in a sector with (F_1+1) firms is zero. For any sector and a given vector of productivity, the subgame starting in stages (iii) and (iv) is essentially the model in the main text. After discrete choices are made in stage (iii), let $\mathcal{O}_s$ and $\mathcal{O}_s^*$ be the set of non-differentiated, exporting firms in sector j in Home and Foreign, respectively. Let $\mathcal{D}_j$ be the set of differentiated firms. Denote with p_i the price of firm $i \in \mathcal{O}_j \cup \mathcal{O}_j^* \cup \mathcal{D}_j$. Define the price index in sector j as

$$V_j = \left[\left(\sum_{i \in \mathcal{O}_j \cup \mathcal{O}_j^*} p_i^{1-\sigma} \right)^{\frac{1-\eta}{1-\sigma}} + \sum_{i \in \mathcal{D}_j} p_i^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

V_s is continuous and differentiable in the vector of productivity ϕ given sets $\mathcal{O}_j$, $\mathcal{O}_j^*$ and $\mathcal{D}_j$. Moreover, since the number of firms and discrete choices are finite, there is only a finite number of discontinuities in V_s as a function of ϕ unconditional on equilibrium discrete choices. Note that firms never set markups above $\eta/(\eta-1)$. Then, since the support of ϕ is finite, the expectation of $V_s^{1/(1-\eta)}$ over sectors is well defined for any integer number of firms. The overall price index is then well defined:

$$\overline{P} = \left[\mathbb{E}_j V_j^{1-\eta} \right]^{1/(1-\eta)}$$

Note that the expected price V_j is strictly smaller in the subset of sectors with (F_1+1) firms. Then, $\overline{P}$ is strictly decreasing in α. As the number of firms go to zero ($F_1 \to 0$, $\alpha \to 1$), the price index goes to infinity. It is also straightforward to show that expected profits go to zero if $F_1 \to \infty$. Then, there exists a unique entry decision in stage (i), and a unique subgame perfect equilibrium.

Proposition There is a unique subgame perfect equilibrium. The entry decision in stage 1 is given by $F_1 \in \mathbb{Z}_+$ and $\alpha \in [0,1)$ and by a corresponding price index $\overline{P}$ such that an entrepreneur is indifferent between not entering and entering a sector with F_1 firms.

We now turn to the results in the theory section of the main text.

Proposition 1: Exit. *In each sector and country, there exist two thresholds $\tilde{\phi}^E \leq \tilde{\phi}^{NE} > 0$ such that exporting firms produce if and only if $\phi \geq \tilde{\phi}^E$ and non-exporting firms produce only if $\phi \geq \tilde{\phi}^{NE}$.*

Cutoff $\tilde{\phi}$ is decreasing in $\overline{P}$, and increasing in costs c_D and c_0.

As in the main text, the proposition holds because the most productive firms have a first-mover advantage. The statement now only holds within countries, because the realized vector of productivity within a sector may differ across countries. So, less productive firms may survive in a country-sector whose price index is higher. The statement of the proposition was thus modified to include the phrase "in each sector and country." The threshold is higher for exporting firms because of they get higher profits if they remain non-differentiated.

Proposition 2 on investment was entirely derived from a firm's problem, whose set up does not change.

Proposition 3: Import competition. The original statement of the proposition is: *A sufficiently large decrease in import tariffs increases exit. Among surviving firms, it increases investment in differentiation. The markup increases for firms that invest in differentiation, and it decreases for other firms.*

The statement refers to the partial equilibrium analysis of decreasing d unexpectedly in a single sector after stage (ii). It holds unchanged in this definition. The corresponding general equilibrium shock is a decrease in d that occurs in all sectors before stage (i). Then, standard arguments imply that a decrease in trade cost d decreases the number of entering firms and overall price index $\overline{P}$. So, in this sense, exit increases. The effect on investment now becomes ambiguous. For exporting firms, the gains from differentiation decreases since only non-differentiated varieties are tradable. Firms gain from the standardization of their products.

For non-exporting firms in the main text, profit from differentiation was not affected by import competition. Here, in contrast, $\overline{P}$ decreases, decreasing both π_D and π_0. We then find conditions under which these firms invest. Consider a marginal change in d holding the firm's competitors discrete choices constant. The firm's gain from differentiation as before as:

$$G = \pi_D - \pi_0 - (f_D - f_0)$$

where gross profits are defined as in the main text:

$$\pi_D = \frac{\overline{P}^{\eta-1}}{\eta}\left(\frac{\eta c_D}{(\eta-1)\phi}\right)^{1-\eta}$$
$$\pi_0 = \overline{P}^{\eta-1}\frac{P_0^{\sigma-\eta}}{\epsilon}\left(\frac{\epsilon c_0}{(\epsilon-1)\phi}\right)^{1-\sigma}$$

Using the Envelope Theorem and taking derivatives, we have

$$\frac{dG}{d(d)} = \frac{\eta-1}{\overline{P}}\frac{d\overline{P}}{d(d)}(\pi_D - \pi_0) + (\sigma-\eta)(\sigma-1)s_i\pi_0\frac{dP_{0-i}}{d(d)}$$

where, recall, s_i is the firm's market share if she is non-differentiated. The first term is a market size effect that decreases the overall gain from investing. The second term is positive. So, in general equilibrium, large and profitable non-exporting firms are the ones that are most likely to invest.

The derivative of G matters for firms that are close to the threshold of exporting, $\pi_D - \pi_0 \approx f_D - f_0$. Then, if $f_D < f_0$, investment always increases. Otherwise, it increases for large non-exporting firms only.

Lemma 4: Missallocation of labor *For any two non-differentiated firms, constrained planner 1 allocates relatively more labor to the more productive firm compared to the market. Constrained planner 1 also allocates more labor to differentiated varieties relative to non-differentiated varieties.*

Proposition 5: Welfare Distortions on Investment and Exit. *Relative to constrained planner 2 and the unconstrained planner, the market features too much entry of unproductive, non-differentiated varieties in $\mathcal{O}$ and too little investment in differentiation.*

Corollary *Compared to a scenario where firms are forced not to change their discrete choices, the exit of the least productive firms from nest $\mathcal{O}$ and the increase in investment induced by import competition is always welfare enhancing.*

The text of the welfare results are replicated above for easier reference. To discuss welfare we consider a planner who cares about world welfare. Since non-differentiated varieties are tradable, a planner who cares only about the welfare of one country would clearly reallocate production for domestic consumption only. So, results for the domestic planner are uninteresting. The proof of lemma 4 and proposition 5, whose statement appears above, relies only on heterogeneous markups and holds unchanged. The only change is in the corollary. As the discussion above makes clear, it is no longer the case that trade always increases investment. Exporting firms may decrease their investment in order to take advantage of new exporting opportunities. Non-exporters generally increase investment to escape competition, but even then, the effect of trade on these firm's investment is ambiguous if $f_D > f_0$, because trade decreases the overall price index $\overline{P}$. So, even if the relative profit of staying non-differentiated π_0/π_D decreases, the absolute gain from investing may also decrease. Then, the statement of the corollary is made considerably weaker. It should be:

Modified Corollary *Compared to a scenario where firms are forced not to change their discrete choices, the exit of the least productive firms from nest $\mathcal{O}$ is always welfare enhancing, and any increase in investment by non-exporters increases welfare.*

E.3 Gravity with Homogeneous Firms

As with other models of industrial organization, large firms interact strategically. A firm's discrete choice depends on the whole distribution of productivity ϕ in the sector of the firm—not only on aggregate statistics as in monopolistic-competition models. Moreover, depending on the distribution of productivity, the equilibrium set of firms investing is generally not a convex function of productivity ϕ. While these features of the model are useful to derive predictions on firm behavior in partial equilibrium, they make it infeasible to, departing from an exogenous distribution of productivities across sectors, get the distributions of price indices P_n and aggregate to the country-wide price index $\overline{P}$.

To get around this issue, we assume in this section that, within countries, firms have the same productivity. Firms still have mass, but we ignore that the equilibrium number of firms in each nest may not be an integer, following the literature. Then, the equilibrium number of differentiated and non-differentiated firms is pinned down by arbitrage conditions. Although assumption of symmetric firms is restrictive, it is still useful to derive gravity-type expressions for aggregate trade flows.

The environment. There are M countries. We denote the importing country with m and the exporting country with j. Labor is the unique factor of production and it is traded in a perfect market. The supply of labor in country j is L_j and wages is w_j. There is a finite and exogenous set of nests $N \subset \mathbb{Z}$.[5] Nests differ on their technologies, trade costs, and preferences.

Preferences. Preferences are nested CES as before. Countries may differ in their preferences over nests. This is a reduced-form way of capturing the notion that nests represent market niches that may appeal to local preferences and to other countries with similar income levels or cultural attributes. Spending of of country m on nest n is[6]

$$X_n = \left(\frac{P_{nm}/A_{nm}}{\overline{P}_m}\right)^{1-\eta} \overline{X}_m \tag{E.1}$$

$$\text{where} \quad \overline{P}_m = \left[\int_n (P_{nm}/A_{nm})^{1-\eta} dn\right]^{1/(1-\eta)}$$

A_{nm} are nest- and importer-specific preference shifters, $\overline{P}_m$ is the overall price index in country m, and $\overline{X}_m = L_m w_m$ is total spending in country m. The price index of nest n in country m is

$$P_{nm} = \left[\sum_{i\in n} p_m(i)^{1-\sigma_n}\right]^{1/(1-\sigma_n)} \tag{E.2}$$

where n represents the set of varieties in nest n with a slight abuse of notation. Since trade costs below are variable, this set is the same for all countries. The price of variety i in country m is $p_m(i)$, generally depends on the importing country. The elasticity of substitution across varieties within nest n is σ_n. It potentially varies across nests to capture the notion that poor countries goods may be more substitutable than rich countries goods, as in Fieler (2011).

[5] Alternatively, one can assume that the set of nests is continuum as in the main text, but that they are classified into a finite set of type s. The conclusions from this alternative specification are the same as the current model, but the notation is heavier.

[6] This demand function arises from preferences represented by

$$\left[\sum_{n\in N} (A_{nm} Q_n)^{(\eta-1)/\eta} dn\right]^{\eta/(\eta-1)}$$

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

Spending in country m on a variety in nest n with price p is

$$x_{nm}(p) = \left(\frac{p}{P_{nm}}\right)^{1-\sigma_n} X_n.$$

Technologies. There is free entry. For all firms in country j, the fixed cost to produce in a variety in nest n is $f_{nj}w_j$ and the marginal cost is $c_{nj}w_j$.

International trade. Trade costs take the form of an iceberg cost. To deliver one unit of a variety of nest n from country j to country m, d_{nmj} units must be shipped. We assume $d_{nmm} = 1$ and the triangle inequality $d_{\tau mj}d_{\tau j'm} \geq d_{\tau j'j}$.

The price in country m of a variety in nest n produced in country j is

$$p_{nmj} = \mu_{nmj}d_{nmj}c_{nj}$$

where $d_{nmj}c_{nj}$ is the marginal cost and μ_{nmj} is the markup. As in the main text, the markup is $\mu_{nmj} = \epsilon_{nmj}/(\epsilon_{nmj} - 1)$ where

$$\epsilon_{nmj} = \sigma_n(1 - s_{nmj}) + \eta s_{nmj}$$

and s_{nmj} is the market share of each firm (below).

Let F_{nj} be the number of varieties in nest n produced in country j. The price index of nest n in country m in equation (E.2) becomes

$$P_{nm} = \left[\sum_{j=1}^{M} F_{nj}p_{nmj}^{1-\sigma_n}\right]^{1/(1-\sigma_n)}$$

Country m's spending in nest n is

$$X_{nm} = (P_{nm}/A_{nm})^{1-\eta}\overline{P}_m^{\eta-1}\overline{X}_m$$

as per equation (E.1). Country m's imports from country j in nest n is

$$\frac{X_{nmj}}{X_{nm}} = F_{nj}\left(\frac{p_{nmj}}{P_{\tau m}}\right)^{1-\sigma_n} \tag{E.3}$$

and the market share of an individual firm is $s_{nmj} = X_{nmj}/F_{nj}$.

Equilibrium. The zero-profit condition is

$$\sum_{m=1}^{M} \frac{X_{nmj}}{F_{nj}\epsilon_{nmj}} - f_{nj}w_j \leq 0 \qquad \text{for } j = 1, ..., M, \ \tau = 1, 2 \tag{E.4}$$

with equality whenever $F_{nj} > 0$. Labor market clearing is

$$w_j L_j = \sum_{n \in N} \sum_{m=1}^{M} X_{nmj} \qquad \text{for all } j = 1, ..., m. \tag{E.5}$$

An equilibrium is a set of wages w_j and number of firms for each country and type F_{nj} that satisfy equations (E.4) and (E.5). Except for the pricing-to-market element, this system is the same as in gravity models with multiple sectors. It is also worth emphasizing that nests here are not interpreted as sectors, but as market niches that may occur within sectors or across sectors if the firm's variety is interpreted as a bundle of services and manufacturing. In sum, the model is sufficiently flexible to capture models that have successfully improved upon gravity in explaining cross-sectional patterns of bilateral trade flows.

E.3.1 Characteristics of Equilibrium

Trade Flows and Gravity. To compare the model to a Krugman model with multiple nests, we note that the ratio of trade flows satisfies

$$\frac{X_{nmj}/X_{nm'j}}{X_{nmj'}/X_{nm'j'}} = \left(\frac{d_{nmj}\mu_{nmj}/(d_{nm'j}\mu_{nm'j})}{d_{nmj'}\mu_{nmj'}/(d_{nm'j}\mu_{nm'j'})}\right)^{1-\sigma_n} < \left(\frac{d_{nmj}/d_{nm'j}}{d_{nmj'}/d_{nm'j}}\right)^{1-\sigma_n}$$
$$\text{if} \quad \left(\frac{d_{nmj}/d_{nm'j}}{d_{nmj'}/d_{nm'j}}\right)^{1-\sigma_n} > 1$$

That is, the elasticity of trade with respect to trade costs d is smaller than the elasticity in a multi-sector Krugman model, $(1 - \sigma_n)$, because of variable markups. When firms sell to distant destinations they do not fully pass through the increase in marginal cost to the consumer. This effect, however, is unlikely to be identified through cross-sectional trade flows because markups are a decreasing function of trade costs which are generally not observable.

The pertinent question then is how aggregate trade flows depart from gravity. Apart from variable markups, the model in a cross section a generalized version of Fieler (2011), who puts more structure on both preferences and technologies. In her estimated model, goods produced and consumed disproportionately in poor countries have a higher elasticity of trade with respect to distance than rich countries' exports. Like the empirical application of Adão, Costinot, Donaldson (2017), the elasticity of substitution between Chinese exports and other poor countries' exports is higher than the elasticity of substitution between Chinese exports and rich countries' exports. Similar findings appear in Costa-Scottini (2017), Lashkaripour (2017). The model is also sufficiently flexible to include cultural attributes in preferences, as in the static version of Morales et al. (2017).

Reductions in Trade Costs and Shifts in Production. We study the effect of trade on domestic profits. This exercise is interpreted as a partial equilibrium effect of a unilateral trade liberalization. The domestic, gross profit of a firm in country m and type n is

$$\pi_{nm} = \max_{p} (\overline{P} A_{nm})^{\eta-1} \overline{X} P_{nm}^{\sigma_n - \eta} p^{\sigma_n} (p - c_{nm})$$

where we write the price index P_{nm} as

$$P_{nm} = \left(p^{1-\sigma_n} + (F_n - 1) p_{nmm}^{1-\sigma_n} + (P_{nm,-m})^{1-\sigma_n}\right)^{1/(1-\sigma_n)}$$
$$\text{where} \quad (P_{nm,-m})^{1-\sigma_n} = \sum_{j \neq m} F_{nj} (t d_{nmj} \mu_{nmj} c_{nj})^{(1-\sigma_n)}$$

is the price index in country m of foreign goods of type n and p_{nmm} is the equilibrium domestic price of nest n. To evaluate changes in trade costs, we take the derivative of π_{nm} with respect to the added constant t and evaluate it at $t = 1$. By the envelope theorem, this derivative is:

$$\left.\frac{d\pi_{nm}}{dt}\right|_{t=1} = (\sigma_n - \eta) f_{nm} (1 - F_{nm} s_{nmm})$$

where we use the zero profit condition, $\pi_{nm} = f_{nm} w_m$ and normalize $w_m = 1$. A reduction in trade costs leads firms in country m to shift toward nests with smaller decreases in profits, i.e., nests where the derivative above is small. These nests are more differentiated (σ_n is small), and generally have larger domestic market shares $(1 - F_{nj} s_{nmm})$. Consistent with our partial equilibrium baseline model, in a Krugman-type model, domestic market shares are larger where demand is larger (preference parameter A_{nm} is large).

F Moments of the Calibration

Table F.1 shows the moments used to calibrate the model, and the model's fit. We match the fitted values of a polynomial regression of TFP on sales, evaluated at each of the percentiles of the sales distribution shown on the table.

Table F.1: Moments from the Calibration, Data and Model

Distribution of Sales (all firms, data = model)									
percentiles	1%	5%	10%	25%	50%	75%	90%	95%	99%
value of sales	-1.485	-1.233	-1.090	-0.780	-0.204	0.572	1.371	1.857	2.674
Polynomial regression of TFP on sales evaluated at the values of sales above									
Unskill-intensive firms									
data	-0.046	0.111	0.171	0.254	0.328	0.413	0.506	0.539	0.584
model	0.141	0.170	0.184	0.212	0.258	0.323	0.412	0.485	0.641
Skill-intensive firms									
data	0.118	0.215	0.257	0.324	0.403	0.491	0.584	0.629	0.669
model	0.219	0.256	0.275	0.313	0.372	0.445	0.534	0.602	0.751

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