Misallocation and Technology Upgrading under Trade Liberalization

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Abstract

This paper examines the influence of resource misallocation on firms' technology investment decisions and its impact on trade gains in developing countries. Literature finds that trade liberalization in distorted economies could result in limited gains or even losses due to worsening resource misallocation. However, trade can also promote technology upgrades and innovation. To explore whether the innovation channel can enhance the gains from trade, I construct a two-country Melitz model with firm-specific distortions and introduce the choice of research and development (R&D) investments. A quantitative assessment using Chinese manufacturing data shows that allowing firms to upgrade technology further reduces welfare gains from trade in this second-best environment. This is because misallocation distorts firms' R&D decisions, therefore trade liberalization encourages the growth of less productive but subsidized firms. This drives up costs for more productive yet taxed firms, resulting in a further reduction of trade gains. Even with additional R&D subsidies aimed at correcting distortions in innovation decisions, results remain unchanged. The paper emphasizes the importance of structural reforms to maximize trade gains in developing countries.

***Keywords*—** distortions, misallocation, technology upgrade, trade liberalization, gains from trade

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1 Introduction

Understanding how globalization affects aggregate productivity and welfare, as well as why its impact differs across countries, are key questions in economics. The trade literature has emphasized two channels: trade integration (1) reallocates production factors towards firms that export, which are the most productive firms, therefore inducing a better allocation of resources *between firms* (Melitz (2003)); (2) increases the rate of return to a firm's investment in new technology or adoption of better technology, leading to productivity improvement *within firm* (Bustos (2011)).

Nevertheless, these mechanisms rely on the assumption that the economy is efficient. Many developing countries, however, are subject to prevalent policy and institutional distortions. Examples include preferential access to land and capital, explicit and implicit taxes and subsidies to certain firms, industrial policies, and many others. In their influential work, Hsieh and Klenow (2009) demonstrates that these distortions lead to a substantial misallocation of resources across firms, resulting in a decline in overall aggregate productivity. Therefore, how the distortions affect the trade gain on welfare and productivity becomes a natural and important question.

To investigate, this paper incorporates firm-specific distortion into a two-country Melitz model. Firms differ in productivity and their level of distortions, which are modeled as taxes or subsidies on firms' output (wedges). These wedges are designed to capture the wide array of policy distortions that developing countries often confront. Firms make simultaneous decisions regarding entry, exit, export, and a one-time R&D investment. Furthermore, firms also determine the extent of improvement on the current productivity they aim to achieve, conditional upon choosing to invest in R&D. This assumption takes into account the potential difference in TFP growth between more and less productive firms.

The presence of distortion masks the firm's true productivity. A firm may be producing in the market not due to inherent productivity but because of subsidies (smaller output wedge). With substantial subsidies, it may also be able to cover the costs of exporting and investing in technology upgrading, even if its inherent productivity remains low. Conversely, firms with high productivity and output wedges (akin to 'taxes') that were able to survive and expand would be driven out as the other firms gain market share and push up costs.

As trade costs decrease, the potential profit from serving foreign markets increases. Subsidized, yet less productive firms begin to export or increase their exports, drawing more resources from their more productive counterparts. The additional profit earned through exporting provides these firms with greater incentives to invest in R&D. Although they also choose a higher level of technology, partially mitigating overall misallocation by reducing the correlation between the output wedge and productivity, this choice results in an expanded fiscal burden. As a result, it ultimately diminishes household wealth and consumption. In other words, the presence of firm-specific output wedges distorts both the between-firm channel by creating negative selections and deteriorating resource allocation, and the within-firm channel by allocating resources to foster the growth of less suitable firms.

Crucially, the correlation between productivity and distortions plays a pivotal role in determining the magnitude of trade gains in aggregate productivity and welfare. When these two variables exhibit a strong and positive relationship, indicating that more productive firms face higher taxes, the overall benefits from trade diminish. This pattern is affirmed as the case in China as Bai et al. (2019) (henceforward BJL), and is supported through the calibration of this model, establishing China as a well-suited case for examination. As documented by Hsieh and Klenow (2009), China represents an economy characterized by many distortions. Moreover, China has undergone an important trade liberalization event, which is also accompanied by a notable increase in R&D expenditure and a growing emphasis on innovation by the government.

In the quantitative analysis, I extend the model by including heterogeneity in the cost of export and innovation. To estimate the parameters, I use China manufacturing firm-level data from 2005. The model is calibrated to match the key moments of the firms' participation in export, R&D, and their correlations with distortion and productivity. Then I use the estimated model to quantify the impact of trade liberalization. In particular, I calculate the welfare gains and aggregate productivity improvements when moving the economy from autarky to an open one, and compare these outcomes with those of a counterfactual efficient economy.

The result shows that distortions significantly offset the potential welfare gains from trade and improvements in productivity. When examining the specific sources contributing to the TFP improvement, a distorted economy indicates a negative contribution from resource reallocation among incumbent firms, a negligible contribution from firms exiting the market, and suggests that the primary contribution comes from within-firm improvements. This pattern aligns with the findings of Brandt et al. (2020). In contrast, the decomposition of an efficient economy offers a different perspective, with improvements primarily stemming from resource reallocation and the exit of less productive firms. This mirrors the observations in advanced countries, as discussed by Bartelsman and Dhrymes (1998).

Lastly, I use the calibrated model to conduct a series of counterfactual policy experiments. In the first exercise, I reduce the variance of output wedges by 50% in the open economy. This reduction in misallocation leads to a significant increase in welfare and encourages more firms to invest in R&D and upgrade their technology. Another set of counterfactual experiments explores the effort of additional policy support for innovation and competition, such as R&D subsidies or a reduction in export or R&D fixed costs. Unsurprisingly, all of these policies lead to a higher proportion of firms engaging in R&D and exporting, thereby enhancing the within-firm channel of trade liberalization. However, due to the unresolved negative impact of distortions on selection and reallocation, the welfare gains show only minimal changes.

Related Literature. This paper contributes to several strands of literature. Firstly, it builds upon a well-established body of macroeconomic studies that examine the effects of resource misallocation, following the seminal work by Hsieh and Klenow (2009) and Restuccia and Rogerson (2008). Notable studies have explored various dimensions within this literature, such as the relationship between misallocation and finance (Midrigan and Xu (2014)), its impact on economic growth (König et al. (2022)), and many others. One significant part of this field explores the relationship between trade and misallocation. Researchers have looked into issues like firm-level distortions (Bai et al. (2019), Berthou et al. (2019), Bajgar (2016)), the impact of distortions on input-output structure (Caliendo et al. (2022), Baqaee and Farhi (2019)), interactions of distortions with trade policy (Bartelme et al. (2019)), see Atkin and Khandelwal (2020) for reviews of resent works.

Among these studies, this paper is most closely related to BJL. Their work examines the effects of bilateral liberalization in the presence of a firm-specific output wedge, and it builds a two-country model calibrated to the Chinese economy. Compared to them, I introduce R&D and technology improvement choices for firms. I find that even with this potential channel that could enhance the gains from trade, the results remain largely consistent. This is because distortions allow the wrong firms to grow, wasting resources that could be used in production and more productive firms.

This paper also contributes to the literature analyzing the effects of trade on technological change. Bustos (2011) extends Melitz (2003) with endogenous decision of both export and innovation, and predicts that the effect of tariff reductions is greatest for firm in the upper-middle range of the firm-size distribution. Costantini and Melitz (2008) and Aw et al. (2011) put it into a dynamic environment. Recent work also includes more detailed discussion on process and product innovation (Atkeson and Burstein (2010), Dhingra (2013)), knowledge spillover (Buera and Oberfield (2020), Alvarez and Lucas (2013)), adoption (Perla et al. (2021)), importance of selection (Sampson (2016)), and many others (see Melitz and Redding (2021) for a more comprehensive review). This paper contributes to this literature by considering firm-specific distortions. The presence of distortions masks the firms' true productivity, therefore both selection and firm's own effort on the adoption rate or intensity are different from the first best economy.

More broadly, this paper contributes to the fundamental question of the gains from trade (Arkolakis et al. (2012),Melitz and Redding (2015)). The standard welfare results in efficient economy no longer hold in the presence of resource misallocation. This paper shows that to value how misallocation impacts the welfare and aggregate TFP, two more components are important: (1) the aggregate output-input ratio regarding production of domestic, export, and R&D; (2) changes in subsidies in output relative to input in terms of trade shocks for domestic, export and R&D.

In exploring the benefits of trade liberalization for developing countries, Goldberg et al. (2010) underscores the significance of utilizing imported intermediate goods, while Dix-Carneiro et al. (2021) delves into the impact of imperfectly enforced regulations and informal sectors. The paper by Farrokhi and Pellegrina (2023) focuses on technology upgrading in the agriculture sector, Lagakos (2016) concentrates on complementary durable goods and the retail trade sector, and Khandelwal et al. (2013) scrutinizes the textile and clothing sector. Farrokhi et al. (2023) explores the technology adoption under distortions, with the focus on technology-specific misallocation. This paper extends this literature by examining misallocation arising from general policy distortions.

The rest of the paper is organized as follows. Section 2 lays out the theoretical model. Section 3 presents comparative statics and analytical results under special cases from the model. Section 4 introduces the data and some descriptive evidence. Section 5 describes the calibration of the model. Section 6 presents our quantitative results and counterfactuals. Lastly, section 7 concludes the paper.

2 Model

This section presents a static model that examines the decision-making process for firms to enter the export market and upgrade their technology when firms are facing distortions. The world consists of two large economies: Home and Foreign. Countries may differ in the size of labor and distribution of firms. Labor is inelastic and immobile across countries.

Household. A representative household in each country makes decisions on the amount of final consumption (C) to maximize utility $u(C)$, and it derives income from wages and government transfers (T).

$$PC = wL + T \tag{1}$$

where P is the price of final good, w is the wage, L is the total labor force endowed.

Final Goods Producer. The final good producers are perfectly competitive. They purchase intermediate varieties from both countries and use a CES function to combine these varieties into the final good.

$$Q = \left[\int_{\omega \in \Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} + \int_{\omega^f \in \Omega_x^f} q(\omega^f)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where ω and ω^f are varieties produced from Home and Foreign that serve Home market, Ω is the endogenous set of goods, σ is the elasticity of substitution across varieties. The final goods producer's problem yields the price index equation and demand function for each intermediate variety ω, where $p(\omega)$ is the price of ω in the market

$$P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} + \int_{\omega^f\in\Omega_x^f} p(\omega^f)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{3}$$

$$q(\omega) = \left(\frac{p(\omega)}{P}\right)^{-\sigma} Q \tag{4}$$

Intermediate Goods Producers. There is a competitive fringe of potential entrants in both economies. They face uncertainty about their status and need to pay an entry sunk cost f_e to enter the market. This status s consists of four components: productivity z, output wedge τ which can be a subsidy ($\tau < 1$) or a tax ($\tau > 1$) on every revenue earned, ability to connect to foreign buyers c_x and the ability to conduct innovation c_i. After paying the sunk cost of entry, the status $s = (z, \tau, c_x, c_i)$ is realized by drawing from a joint distribution G, independently across firms. Firms are monopolistically competitive, producing their own variety ω by using labor-only technology.

A firm has the option to exit the market immediately if its draw cannot generate positive profit serving the domestic market, where the firm solves[1]:

$$\begin{aligned}\pi_d(s) &= \max_p \frac{pq}{\tau} - \frac{w}{z}q - wf_d \\ &= \Pi_d w z^{\sigma-1}\tau^{-\sigma} - wf_d \end{aligned} \tag{5}$$

where $\Pi_d := \frac{P^\sigma Q w^{-\sigma}}{\sigma^\sigma(\sigma-1)^{1-\sigma}}$ is taken as given by the firms. The fixed costs result in a productivity threshold, below which the firm chooses to exit

$$\bar{z}_d(\tau) = \left[\frac{f_d}{\Pi_d}\tau^\sigma\right]^{\frac{1}{\sigma-1}} \tag{6}$$

After the firm makes the entry decision, it can then decide whether to engage in export and/or make a one-time investment in R&D simultaneously. Export subjects to iceberg cost $D > 1$ and fixed cost $c_x \cdot f_x$, where f_x is common across all firms and c_x is the firm's own ability to connect for-

[1]Equilibrium price is $p = [\sigma/(\sigma-1)](w\tau/z)$

eign markets. For those firms that choose export but not upgrade technology solve the following problem [2]

$$
\begin{aligned}
\pi_x(s) &= \max_{p_x} \frac{p_x q_x}{\tau} - \frac{w}{z} D q_x - w c_x f_x \\
&= \Pi_x w D^{1-\sigma} z^{\sigma-1} \tau^{-\sigma} - w c_x f_x
\end{aligned} \tag{7}
$$

where $\Pi_x := \frac{P^{*\sigma} Q^* w^{-\sigma}}{\sigma^\sigma (\sigma-1)^{1-\sigma}}$, with P^* and Q^* denoting the aggregate price index and demand abroad.

R&D investment is also subject to a fixed cost $c_i \cdot f_i$, where f_i is the common component, c_i is the heterogeneous part. Additionally, firms can select the intensity of their innovation efforts, denoted as α. A higher intensity of innovation leads to more significant productivity increase or higher technology upgrading, transforming z into $z' = z(1+\alpha)^{\frac{1}{\sigma-1}}$. The cost incurred follows the formula:

$$
A\alpha^\beta z^\theta
$$

where β is assumed to be positive and greater than 1, reflecting that greater productivity improvements are associated with higher costs. θ, on the other hand, can be positive, negative, or zero, depending on the difference in the growth rate between highly productive and less productive firms within the country.

Given that both domestic and export profits increase with productivity, firms will always find it beneficial to invest in R&D to enhance their profits, as long as they can cover the fixed costs. The additional profit earned by technology upgrading for those firms only serve domestic market is

$$
\begin{aligned}
\pi_d^i(s) &= \max_\alpha \left\{ \pi_d(z', \tau, c_x, c_i) - \pi_d(s) - A\alpha^\beta z^\theta w - w c_i f_i \right\} \\
&= \max_\alpha \left\{ \Pi_d w z^{\sigma-1} \tau^{-\sigma} \alpha - A\alpha^\beta z^\theta w - w c_i f_i \right\}
\end{aligned} \tag{8}
$$

Similarly, firms engage in both export and R&D solve additional profit maximization problem of

$$
\pi_x^i(s) = \pi_x(s) + \max_\alpha \left\{ (\Pi_d + \Pi_x D^{1-\sigma}) w z^{\sigma-1} \tau^{-\sigma} \alpha - A\alpha^\beta z^\theta w - w c_i f_i \right\} \tag{9}
$$

[2] Similar to domestic only firm's problem, $p_x = [\sigma/(\sigma-1)]\,(wD\tau/z)$, and $q_x = (p_x/P^*)^{-\sigma} Q^*$

The optimal intensity and the productivity cutoff for technology upgrading are [3]

$$\alpha^* = \left(\frac{(\Pi_d + 1_x \Pi_x D^{1-\sigma})\tau^{-\sigma} z^{\sigma-1-\theta}}{\beta A} \right)^{\frac{1}{\beta-1}} \tag{10}$$

$$\bar{z}_i(s)^{\frac{\beta(\sigma-1)-\theta}{\beta-1}} = \frac{c_i f_i}{B(\Pi_d + 1_x(s)\Pi_x)^{\beta/(\beta-1)}} \tau^{\frac{\sigma\beta}{(\beta-1)}} \tag{11}$$

As emphasized by the previous literature, technology and export decisions are interdependent. Engaging in export leads to increased profits for the firm, making it easier to cover the fixed costs of R&D and variable cost of choosing greater improvement — as in the model, α is higher when the firm also exports. Conversely, investments in R&D provide the firm with an opportunity to enhance its productivity, resulting in higher profits for both domestic and foreign market. It may also enable the firm to cover the fixed costs associated with exporting, thereby entering the foreign market.

Intermediate firms therefore make export and R&D decisions by comparing the total profit of each of the four possible choices (5), (7), (8), (9).

$$\pi(s) = \begin{cases} \pi_d(s) + \max\{0, \pi_x(s), \pi_d^i(s), \pi_x^i(s)\} & \text{if } \pi_d(s) > 0 \\ 0 & \text{otherwise} \end{cases}$$

Government. The government's budget is balanced, therefore the lump-sum transfers are determined as follows

$$T = \int_{\omega \in \Omega} \left(1 - \frac{1}{\tau}\right) p(\omega) q(\omega) d\omega$$

The endogenous set of goods Ω includes all goods produced at Home selling to all destinations.

Equilibrium. With firm distribution of $s = (z, \tau, c_x, c_i)$ for Home G and Foreign G^*, labor endowment at Home L and Foreign L^*, the equilibrium is a collection of aggregate variables $\{P, P^*, w, w^*, Q, Q^*, C, C^*, T, T^*\}$, total firm mass $\{M, M^*\}$, price and quantities of intermediate goods $\{p(s), q(s), p_x(s), q_x(s)\}$ and their counterparts for Foreign firms, decision $\{1_d(s), 1_x(s), 1_i(s), \alpha(s)\}$ and the labors for domestic and export production, as well as innovation $\{l_d(s), l_x(s), l_i(s)\}$ (and their

[3] The constant $B = \left(\frac{A\beta^\beta}{(\beta-1)^{\beta-1}}\right)^{\frac{1}{\beta}}$

counterparts for Foreign firms), such that household, final good firm, intermediate good firms all make optimal decisions; and the free entry condition holds:

$$\int_s \pi(s)dG \;=\; wf_e \tag{12}$$

good and labor market clearing conditions hold:

$$Q = C$$

$$M\left[\int_{\bar{z}_d} \left(l_d(s) + f_d\right) dG \;+\; \int_{\bar{z}_d} 1_x(s)\left(l_x(s) + c_x f_x\right) dG \;+\; \int_{\bar{z}_d} 1_i(s)\left(l_i(s) + c_i f_i\right) dG + f_e\right] = L \tag{13}$$

and trade is balanced:

$$P^{*\sigma}Q^{*}w^{1-\sigma}M\int_{\bar{z}_d}\left(\frac{z}{\tau}\right)^{\sigma-1}1_x(s)\Big(1{+}1_i(s)\alpha(s)\Big)dG \;=\; P^{\sigma}Qw^{*1-\sigma}M^{*}\int_{\bar{z}_d^{*}}\left(\frac{z}{\tau}\right)^{\sigma-1}1_x(s)\Big(1{+}1_i(s)\alpha(s)\Big)dG^{*} \tag{14}$$

3 Comparative Statics

This section presents comparative statics and results under special cases from the model, and shows how distortion can lead to a lower welfare and aggregate TFP. To illustrate, I consider a symmetric equilibrium with identical Home and Foreign country.

3.1 Welfare and TFP with distortion

Welfare, denoted as W is evaluated using final consumption per capita C/L, which equals Q/L in the equilibrium, or by a simple algebra $Q/L = (PQ/L)(1/P)$. $PQ/L \;=\; \overline{TFPR}$ is the revenue-based total factor productivity of the economy. Aggregate TFP is defined as $Q = TFP \cdot L$, which has same expression as welfare under symmetric equilibrium. Combining with (**??**), the welfare and TFP has the expression

$$
\begin{aligned}
W = \frac{\sigma-1}{\sigma} M^{\frac{1}{\sigma-1}} \Bigg[& \int_{\bar{z}_d} \left(\frac{\overline{TFPR}}{MRPL_\tau} \cdot z \right)^{\sigma-1} dG && \text{(domestic revenue)} \\
& + D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) \left(\frac{\overline{TFPR}}{MRPL_\tau} \cdot z \right)^{\sigma-1} dG && \text{(export revenue)} \\
& + \int_{\bar{z}_d} (1 - 1_x(s)) 1_i(s) \left(\frac{\overline{TFPR}}{MRPL_\tau} \cdot z \right)^{\sigma-1} \alpha(s) dG && \text{(additional revenue from R\&D)} \\
& + (1 + D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s) 1_i(s) \left(\frac{\overline{TFPR}}{MRPL_\tau} \cdot z \right)^{\sigma-1} \alpha(s) dG \Bigg]^{\frac{1}{\sigma-1}} && (15)
\end{aligned}
$$

where $MRPL_\tau = w\tau$ is the firm-specific marginal revenue product of labor. Welfare has five components: total mass of firm M in the country (or product innovation as in Atkeson and Burstein (2010)), revenue comes from all the domestic sales, revenue comes from export to Foreign, additional revenue from firm engaging in R&D, both from domestic market and foreign market.

This equation points out four sources of TFP and welfare loss in the presence of firm-level distortions. The first one is through the direct misallocation of resources, captured by dispersions in $\frac{\overline{TFPR}}{MPRL_\tau}$. The second one is via selection and entry mechanisms as captured by $\bar{z}_d$ and firm choice over $\{1_x(s), 1_i(s)\}$. As shown in the (6), the entry cutoffs are different for firms facing different levels of distortions. Low-productivity firms that would have been otherwise excluded from the market can now enter the market and survive if sufficiently subsidized. Conditional on surviving, subsidized firms earn higher profits even though they may be less productive, making it easier to cover the fixed costs related to export and innovation.

Thirdly, distortion enters in the technology improvement $\alpha(s)$, as shown from (10). Subsidized firms find it cheaper to choose higher intensity. Lastly, all the aggregate variables P, Q, M are different from their respective efficient levels, therefore causing the welfare to be lower than the first best.

3.2 Welfare and TFP change due to trade

When there is an iceberg cost shock, the latter three components: selection, technology improvement, and aggregate variables change accordingly. In an efficient economy, trade liberalization brings higher profits serving foreign markets, making the productive firms expand. It also creates more competition in the domestic market, forcing the least productive firms to exit. These two lead to an improvement in welfare and aggregate TFP through *between-firm* resource reallocation. With the choice of technology improvement, this force has been reinforced. At the same time, as trade liberalization brings higher profit to the productive firms, these firms now have the ability to choose a higher intensity, leading to a *within-firm* productivity increase.

With distortions, however, both channels can be affected. The presence of distortions can result in the highly subsidized firm expanding, instead of a high productivity firm, leading to an exacerbation of resource reallocation, as emphasized in BJL. Additionally, it encourages the wrong firm to do innovation. Although the subsidy help low productive firm to improve, it creates an unnecessary fiscal burden, which eventually reduce the household consumption and welfare.

To better see this, note that the change in welfare comes from changes in the price index and income. Under the free entry condition where there is zero profit, and the normalization of $w = L = 1$, any changes in income arise solely from variations in fiscal revenue T. As in BJL, the welfare or TFP change $\Delta \log W$ from a small trade cost change can be written as

$$\Delta \log W = \Delta \log Q = -\Delta \log P + \Delta \log(PQ) = -\Delta \log P + \Delta \log(1 + T)$$

In an efficient case without wedges, $T = 0$ and $\Delta \log W = -\Delta \log P$. Therefore, the change of T in terms of the trade cost reduction is key to see how distortion could possibly offset or even cancel out the gain from trade.

To start with, the aggregate price index P have the following expression, after combining the trade balance:

$$
\begin{aligned}
P^{1-\sigma} = \frac{\sigma}{\sigma-1} M \Bigg[& \int_{\bar{z}_d} z^{\sigma-1}\tau^{1-\sigma} dG && \text{(domestic revenue)} \\
& + D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{1-\sigma} dG && \text{(export revenue)} \\
& + \int_{\bar{z}_d} (1 - 1_x(s)) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG && \text{(R\&D extra: non-exporters)} \\
& + (1 + D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG \Bigg] && \text{(R\&D extra: exporters)}
\end{aligned}
\tag{16}
$$

There are four parts within the bracket. The first part comes from the domestic revenue or output of all surviving firms. The second part comes from serving the foreign market for all the exporting firms. The last two are the additional outputs that come from conducting R&D. To save the notation, let's denote Λ as the value of the bracket:

$$
\begin{aligned}
\Lambda = & \int_{\bar{z}_d} z^{\sigma-1}\tau^{1-\sigma} dG + D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{1-\sigma} dG \\
& + \int_{\bar{z}_d} (1 - 1_x(s)) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG + (1 + D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG
\end{aligned}
$$

Denote λ_1,λ_2, λ_3 be the output share of domestic, export, and additional R&D investment over the total output respectively.

$$
\begin{aligned}
\lambda_1 &= \int_{\bar{z}_d} z^{\sigma-1}\tau^{1-\sigma} dG/\Lambda \\
\lambda_2 &= D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{1-\sigma} dG/\Lambda \\
\lambda_3 &= \left(\int_{\bar{z}_d} (1 - 1_x(s)) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG + (1 + D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s) 1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG \right)/\Lambda
\end{aligned}
\tag{17}
$$

Another important equation comes from the combination of labor market clearing condition and free entry condition, which have similar four components, but in terms of labor input.

$$fe = \sigma \frac{P^\sigma Q}{\sigma^\sigma(\sigma-1)^{1-\sigma}} M \bigg[\int_{\bar{z}_d} z^{\sigma-1}\tau^{-\sigma} dG + D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{-\sigma} dG + \int_{\bar{z}_d} (1-1_x(s))1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG + (1+D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s)1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG \bigg] \tag{18}$$

Similarly, define the Ξ as the value of the bracket:

$$\Xi = \int_{\bar{z}_d} z^{\sigma-1}\tau^{-\sigma} dG + D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{-\sigma} dG + \int_{\bar{z}_d} (1-1_x(s))1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG + (1+D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s)1_i(s) z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG$$

Define $S_1,\ S_2,\ S_3$ as the share of input used for domestic, export, and additional R&D.

$$\begin{aligned} S_1 &= \int_{\bar{z}_d} z^{\sigma-1}\tau^{-\sigma} dG/\Xi \\ S_2 &= D^{1-\sigma} \int_{\bar{z}_d} 1_x(s) z^{\sigma-1}\tau^{-\sigma} dG/\Xi \\ S_3 &= \left(\int_{\bar{z}_d} (1-1_x(s))1_i(s) z^{\sigma-1}\tau^{-\sigma}\alpha(s) dG + (1+D^{1-\sigma}) \int_{\bar{z}_d} 1_x(s)1_i(s) z^{\sigma-1}\tau^{-\sigma}\alpha(s) dG \right)/\Xi \end{aligned} \tag{19}$$

Combining (16),(18) and the definition of six shares lead to the following proposition:

Proposition 1: The change of the distortion term $\Delta \log(1+T)$ associated with an iceberg cost shock has the following expression, where the size depends on (1) the aggregate output share λ_i and input share S_i of different groups of firms; (2) the change of aggregate subsidies in the output and input for domestic production, exports and R&D.

$$
\begin{aligned}
\Delta \log(1+T) = {} & \lambda_1 \Delta \log\left(\int_{\bar{z}_d} z^{\sigma-1}\tau^{1-\sigma} dG\right) - S_1 \Delta \log\left(\int_{\bar{z}_d} z^{\sigma-1}\tau^{-\sigma} dG\right) \\
& + \lambda_2 \Delta \log\left(\int_{\bar{z}_d \cap 1_x(s)} D^{1-\sigma} z^{\sigma-1}\tau^{1-\sigma} dG\right) - S_2 \Delta \log\left(\int_{\bar{z}_d \cap 1_x} D^{1-\sigma} z^{\sigma-1}\tau^{-\sigma} dG\right) \\
& + \lambda_3 \Delta \log\left(\int_{\bar{z}_d \cap (1-1_x) 1_i} z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG + (1+D^{1-\sigma}) \int_{\bar{z}_d \cap 1_x \cap 1_i} z^{\sigma-1}\tau^{1-\sigma}\alpha(s) dG\right) \\
& - S_3 \Delta \log\left(\int_{\bar{z}_d \cap (1-1_x) 1_i} z^{\sigma-1}\tau^{-\sigma}\alpha(s) dG + (1+D^{1-\sigma}) \int_{\bar{z}_d \cap 1_x \cap 1_i} z^{\sigma-1}\tau^{-\sigma}\alpha(s) dG\right)
\end{aligned}
\tag{20}
$$

Note that, if firms are not allowed to improve technology, equation (20) is the same as in BJL, where only between firm channel are taken into action. With the choice of R&D, however, there is one more component that contributes to the equation, which itself combines two forces together. One contributes to the *between firm* channel, by moving $1_i(s)$; the other contributes to the *within firm* channel, by changing α.

3.3 Special Cases

To understand how *between firm* and *within firm* channels lead to a negative distortion term $\Delta \log(1+T)$, I analyze two special cases. The first one focuses on the *within firm* channel, where it shuts down the selection mechanism by setting all fixed costs equal to 0; the second one focuses on the *between firm*, where all firms, if they decide to innovate, choose the same $\alpha = \delta$. Both cases assume homogeneous productivity and fixed cost, with only heterogeneity in output wedge τ. Further, $1/\tau$ follows Pareto distribution with parameter θ.

3.3.1 Within-firm channel

Consider a version of the model with zero fixed costs of production f_d, exporting f_x and R&D upgrading f_i. In this case, all firms export and upgrade technology, both in an efficient economy, or in the distorted one. Therefore, this setting removes the selection mechanism and focus only on the impact of within firm technology improvement under distortion.

Proposition 2: Consider an economy with no fixed costs, homogeneous productivity, and Pareto-distributed domestic wedge $1/\tau$ with parameter θ. For a small change in trade cost, the distortion term is always negative.
PROOF: see Appendix B.1.

Under the above assumptions, firm's optimal R&D intensity is:

$$\alpha(\tau) = \left[\frac{(1 + D^{1-\sigma})\Pi_d \tau^{-\sigma}}{A\beta}\right]^{\frac{1}{\beta-1}}$$

where $\Pi_d = \frac{P^\sigma Q}{\sigma^\sigma(\sigma-1)^{1-\sigma}}$.

In an efficient economy, since firms are identical, they choose the same level of α. With distortion, however, subsidized firms will choose higher intensity. Trade further enhance this as subsidized firms expand more compared to less subsidized ones, leading to an increase in total fiscal subsidy to firms, making the misallocation term negative.

3.3.2 Between-firm channel

Now consider the case with fixed cost $0 < f_d < f_x < f_i$. There is no heterogeneity in fixed costs. Firms have homogenous productivity, but heterogeneous wedges, follow Pareto distribution. Further assume the productivity improvement is $(1+\delta)^{\frac{1}{\sigma-1}}$, the same for all innovating firms, regardless of its state. In this setting, most taxed firms (highest τ) exit the market, less taxed firms operating domestically, least taxed or slightly subsidized firms export, and highly subsidized firms export and innovate. Therefore, this case serves as an extended version of BJL by introducing an additional stage to the selection mechanism. It also closely aligns with Bustos (2011), though firms heterogeneity is represented by output wedges rather than productivity.

Proposition 3: Consider a version of the model following the above assumptions. Under a small change in trade cost, the distortion term depends on the aggregate output-input ratio regarding the production of export and R&D, and their relative size.
PROOF: see Appendix B.2.

Under above assumptions, the distortion term can be written as

$$\Delta \log(1+T) = \frac{\sigma - 1}{\sigma}(\theta + 1)\left[(S_2 - \lambda_2) + \frac{D^{1-\sigma}}{1 + D^{1-\sigma}}(S_3 - \lambda_3)\right]\Delta \log D$$

In the Appendix B.2, I show $S_2 + S_3 \geq \lambda_2 + \lambda_3$, but not necessarily with $S_2 + \frac{D^{1-\sigma}}{1+D^{1-\sigma}} S_3 \geq \lambda_2 + \frac{D^{1-\sigma}}{1+D^{1-\sigma}} \lambda_3$. Therefore both aggregate output and input ratios and their relative size matter. If compare this with BJL, where the above equation is always negative in BJL, technology upgrading has the potential to bring benefits to the welfare, since the distortions subsidize firms to engage in productivity improvement. But how important of this channel depends on the how many firms are impacted, and the relative size of λ_3 and S_3.

4 Data and Descriptive Evidence

This section introduces the Chinese firm-level data, and presents several descriptive evidence that align with the model predictions.

4.1 Data

The data for Chinese firms are from the Annual Survey of Industrial Firms (ASIF), conducted by China's National Bureau of Statistics for 1998–2007. It includes all state-owned firms and private firms with more than five million RMB in revenue in the industrial sector[4]. The dataset contains the firm's basic information on the 4-digit industry, age, location, ownership, and variables of wage payments, value-added, and capital stock, as well as trading status. It records firms' R&D spending, though this information is only available after 2004. The raw data consists of over 125,858 firms in 1998 and 306,298 firms by 2007.

Table 1 presents summary statistics for the years 2005-2007, during which the R&D data is available. On average, 30% of firms are involved in exporting, and 10% exhibit positive R&D spending. Following the approach of König et al. (2022), I focus only on the extensive margin of

[4]Despite the reporting threshold for private firms, the survey is representative of the whole secondary industry: When compared to the census of all firms conducted by NBS in 2004, ASIF accounted for more than 90% of both sales and output (Brandt et al. (2014))

R&D, using it as a proxy for innovation or technology upgrading. The reason for not using the level of R&D spending is because this intensive margin is subject to a more severe measurement error. The data reveals that exporters and R&D firms are indeed larger, characterized by higher value-added and more employment. Moreover, among R&D firms, those involved in exports are even more substantial in scale.

Table 1: Summary statistics

	Number of firms	value add(RMB)(in $\log$)	Number of employees(in $\log$)
All	777,702	9.03	4.69
Non-exporter	560,911	8.89	4.48
Exporter	216,791	9.39	5.23
Non-R&D	694,422	8.89	4.61
R&D	83,280	9.96	5.33
Among them:			
R&D, non-exporter	49,905	9.43	4.96
R&D, exporter	33,375	10.29	5.90

4.2 Measure of productivity and distortion

Follow Hsieh and Klenow (2009), firm-specific distortion and productivity can be measured by revenue-based total factor productivity (TFPR) and quantity-based total factor productivity (TFPQ). From their derivations, firms should have same TFPR if there is no distortion present in the economy. TFPQ, on the other hand, represents firms' true productivity z. Relates the definition with this model, TFPR corresponds to the value-added over total inputs (pq/l) and TFPQ corresponds output over total input (q/l), which follows

$$\text{TFPR} = \frac{pq}{l} = \tau\left(1 - \frac{f}{l(s)}\right), \quad \text{TFPQ} = \frac{q}{l} = z\left(1 - \frac{f}{l(s)}\right) \tag{21}$$

where $f = f_d + 1_x c_x f_x + 1_i c_i f_i$ is the total fixed cost paid by the firms, and $l = l_d + 1_x l_x + 1_i l_i$ is the total labor used in production and innovation. Due to the hetergeneity of fixed costs c_i and c_x, in efficient economy, firms make same export and R&D decision still see variations in TFPR, but the variation should be small. Under distorted economy, there will be larger dispersion.

The above equations show why distortions and productivity cannot be directly backed out from the data, as the model includes an endogenous selection (not only $1_x,\ 1_s$, but also the selection of surviving firms) and the unknown fixed costs. Similarly to BJL, these two measures back out from the data will be used to match model moments later in the calibration.

To obtain the measure of TFPQ and TFPR from the data, I follow the methodology proposed by Hsieh and Klenow (2009). σ is set to be 3. The composite inputs with capital and labor are $k_{ij}^{\alpha_i} l_{ij}^{1-\alpha_i}$ for firm j in industry i with labor share α_i. The industry labor shares come from the U.S. NBER productivity database, which is based on the Census and the Annual Survey of Manufactures (ASM). The capital stock is calculated as the book value of fixed capital net of depreciation. Follow König et al. (2022), I regress TFPQ and TFPR on province, industry, and age dummies and take the residual as the measures, to get rid of other factors not consider in the model. Lastly, both TFPQ and TFPR are measured with their deviations from the industry mean.

4.3 Descriptive Evidence

The model generates several testable predictions. Firstly, value-added should be negatively correlated with the output wedge, and positively correlated with productivity. Secondly, regarding the export and innovation investment, subsidized firms and high productive firms should see higher participation in both activities and higher export profits. Lastly, in terms of R&D intensity, subsidized firms should find it cheaper to choose higher α, therefore achieve faster growth in the future.

Table 2 and 3 records the result of related regressions, where I regress the variables of interest with TFPQ, TFPR, and control for several firm characteristics such as ownership (state-owned, or foreign-owned), age, industry, province, and capital stock. All the dependent variables are taken at time $t+1$, where independent variables are at time t.

The result confirms the prediction of the model. As shown in Table 2, columns (1)–(2) shows the pattern of value-added, the result is robust with and without controlling previous period R&D and export participation. Columns (3)-(4) confirm the distorted selection mechanism for exporting, and R&D investment enhances the mechanism. In Table 3, columns (1)-(2) confirm the distorted selection into R&D. Even though with measurement error, R&D spending shows a similar pattern. Lastly, columns (3)-(4) talk to the within-firm channel. Control for current productivity,

Table 2: Chinese firm: value-added and export

	(1)	(2)	(3)	(4)
	log(VA)	log(VA)	1(EXP)	log(Exp value)
log(TFPQ)	1.77***	1.76***	0.13***	1.81***
	(0.005)	(0.005)	(0.005)	(0.070)
log(TFPR)	-1.95***	-1.95***	-0.18***	-2.30***
	(0.007)	(0.007)	(0.007)	(0.089)
1(R&D)		0.06***	0.07***	0.64***
		(0.004)	(0.006)	(0.070)
1(EXP)		0.00		
		(0.005)		
Prov,Ind FE	Y	Y	Y	Y
R-squared	0.77	0.77	0.34	0.37
obs	936,706	423,766	423,766	423,766

Table 3: Chinese firm: R&D

	(1)	(2)	(3)	(4)
	1(R&D)	log(R&D spending)	TFP growth (all)	TFP growth (R&D)
log(TFPQ)	0.13***	1.01***	-0.18***	-0.16***
	(0.006)	(0.048)	(0.007)	(0.016)
log(TFPR)	-0.16***	-1.23***	-0.17***	-0.17***
	(0.007)	(0.059)	(0.010)	(0.022)
1(R&D)			0.05***	
			(0.006)	
1(EXP)	0.04***	0.27***	-0.01	0.02$^{\cdot}$
	(0.005)	(0.032)	(0.005)	(0.010)
Prov,Ind FE	Y	Y	Y	Y
R-squared	0.16	0.21	0.23	0.24
obs	609,751	609,703	314,904	37,581

more subsidized firms grow faster. Also, similar to the findings of König et al. (2022), R&D firms grow faster, though the rate is distorted by the misallocation.

5 Calibration

In this section, I estimate the quantitative effects of trade when accounting for domestic distortions. The two countries Home and Foreign, are calibrated to data corresponding to China and the U.S. The strategy is to use the observed distributions of inputs, value-added, export and R&D participation from Chinese firm-level data to estimate the underlying joint distribution of distortions and productivity in conjunction with other parameters in the model. The general process closely follows BJL, though with different choices of moments to match the model to the data.

5.1 Predetermined parameters

The elasticity of substitution between varieties σ is set to be 3 as in HK. The Home labor$L$ and the entry cost f_e are normalized to 1. Foreign labor L_f is set to be 0.2 to match the relative labor force of the US to China.

Next, I make several assumptions regarding the distribution G for Home and Foreign. Firstly, to better align with the data, I assume that the heterogeneity in fixed costs c_x and c_i has two components, where $c_x = p_x \cdot \bar{c}_x$ and $c_i = p_i \cdot \bar{c}_i$. Both p_x and p_i follow Bernoulli distributions so that only p_x and p_i fraction of firms can engage in export and R&D (other firms draw a fairly large fixed cost so that it will never be optimal to participate in these activities). These restrictions are imposed due to the small correlation between export and R&D participation observed in the data. In the model, however, highly subsidized and productive firm always choose both investment, while taxed and low productive firms engage in neither. Without this restriction, it is difficult to achieve the same model moments as in the data.

For the rest of assumptions, I assume the joint distribution G in home country follows a multivariate log-normal distribution on $(z, \tau, \bar{c}_i)$, similar to BJL. $\bar{c}_x$ is set to be 1. In other words, firms independently draw p_x, p_i, and $(z, \tau, \bar{c}_i)$. If the firm is allowed to export, then it pays f_x as the fixed cost, if the firm is allowed to upgrade technology, then it pays $\bar{c}_i \cdot f_i$ fixed cost to do R&D. The reason for maintaining simplicity in export heterogeneity is rooted in the small correlation observed in the data between TFPR and export participation, as well as TFPQ and export participation. This indicates that the correlation between τ and c_x, as well as z and c_x is also small. Therefore keep c_x independent with (z, τ) can save computational burden. Note that the correlation between TFPR and R&D participation, as well as TFPQ and R&D participation is also small, but since it is the main interest, I keep $\bar{c}_i$ jointly distribute with (z, τ). The mean of the distribution is normalize to 0, therefore the Home distribution is characterized by 3 standard deviations $(\sigma_z, \sigma_\tau, \sigma_{\bar{c}_i})$, 3 correlations $(\rho_{z,\tau}, \rho_{z,\bar{c}_i}, \rho_{\tau,\bar{c}_i})$ and 2 probability (p_x, p_i).

Lastly, Foreign is assumed to be free of distortion. It has the log-normal distribution only on the productivity, with mean μ_f calibrated internally, and same standard deviation as Home σ_z. Furthermore, the problem of Foreign intermediate firm is simplified, with no choice of innovation. The fixed cost of entry f_e, operating f_d, and export f_x, as well as iceberg cost D are assumed to be the same as Home. In the model, the Foreign country only affect Home by its aggregate, through the balanced trade condition and demand function for Home varieties. Therefore the exact actions of foreign intermediate producer is not the focus.

5.2 Parameters estimated via SMM

The remaining 16 parameters, including 8 related to Home distribution, 3 fixed cost f_d, f_x, f_i, 3 from R&D cost function A, β, θ, as well as iceberg cost D, and Foreign mean of productivity μ_f are estimated jointly to match 16 model moments with their data counterparts. Though every parameter matters for the general equilibrium, there are clear correspondence between certain model and data moment. Table 4 reports the estimated parameters and the most relevant moments in the data and model.

Beginning with the distribution parameters, dispersions in distortions τ and productivity z and their correlation are mapped to the observed joint distribution between TFPR and TFPQ in the data. Using the the equation (21), adding the fixed cost and labor to the grid over z and τ gives rise to the model moment. Similarly, the heterogeneity in R&D fixed cost drives the dispersion of R&D participation in the data. Its correlation with productivity and distortion can therefore match with the correlation of R&D participation and TFPQ, TFPR respectively. The result shows $\rho_{z,\tau}$ is positive, meaning high productive firms face large distortion, or in other word, they are taxed. This correlation confirms the previous analysis that fiscal subsidies distort the firms R&D and export decisions, as well as the selection mechanism. The correlation between $\bar{c}_i$ and z, τ is small.

Table 4: Parametrization and Moments

Panel A: parameters of distribution

Parameter	Value	Moment	Data	Model
Std. distortion σ_τ	0.97	Std(TFPR)	0.92	0.93
Std. productivity σ_z	1.26	Std(TFPQ)	1.23	1.23
Corr(distortion, prod) $\rho_{\tau z}$	0.74	Corr(TFPR, TFPQ)	0.89	0.83
Std. R&D cost σ_{c_i}	1.24	Std(R&D part)	0.30	0.29
Corr(distortion, R&D cost)$\rho_{\tau,c}$	-0.05	Corr(TFPR, R&D part)	-0.02	-0.25
Corr(prod, R&D cost) $\rho_{z,c}$	-0.10	Corr(TFPQ, R&D part)	0.09	0.09
Prob of firm allow R&D p_i	0.24	Corr(R&D part, EXP part)	0.10	0.12
Prob of firm allow export p_x	0.38	Std(EXP part)	0.41	0.44

Panel B: parameters of fixed costs, trade, and innovation

Parameter	Value	Moment	Data	Model
Fixed cost of producing f_d	0.04	Frac of firms producing	0.85	0.81
Fixed cost of exporting f_x	0.15	Frac exporter	0.30	0.27
Fixed cost of R&D f_i	0.20	Frac upgrade	0.10	0.08
Iceberg trade cost D	1.65	Import share	0.23	0.24
Mean foreign prod μ_f	1.43	GDP U.S to CHN	1.79	1.80
Innovation cost function A	20	Reg. of Col(1) Tab(3) TFPR	-0.16	-0.17
Innovation cost function β	2.98	Reg of Col(4) Tab(3) TFPQ	-0.16	-0.16
Innovation cost function θ	2.80	Reg of Col(4) Tab(3) TFPR	-0.17	-0.24

The probability of firms that are allowed to export p_x and improve the technology p_i are matched with the standard deviation of exporting participation, and the correlation between export and R&D participation. The data moment suggest the correlation is small, and by setting the restrictions of both activity, the model can match well with this data moment.

Fixed costs of operating f_d is matched with the moment of fraction of firm surviving. A lower f_d will lead to higher fraction of survivors. Firm-level data of the sample periods reveals that roughly an average of 85% of entrants survive into the second year. The estimation value of f_d is small, and the value is not very different from BJL.

Similarly, f_x and f_i controls for the fraction of exporters and fraction of positive R&D firms. Note that the estimated fixed cost have the order of $f_d < f_x < f_i$, indicating engage in exports and R&D posses higher cost. This result corresponds to the finding of literature such as Bustos (2011), though in this model, there is some degree of heterogeneity on the fixed costs for specific firms.

The iceberg cost D is matched by the aggregate import share in Home. The estimated value is slightly smaller than BJL, but in line with the estimate of 1.7 in Anderson and Van Wincoop (2004), and the 1.83 in Melitz and Redding (2015). μ_f, the Foreign productivity mean matches with the GDP U.S. over China.

Lastly, there are three parameters (A, β, θ) in the R&D cost function $A\alpha^{\beta}z^{\theta}$. Note that β is assumed to be greater than 1, since higher improvement associates with higher cost. if θ is positive, more productive firms find difficult to upgrade technology. These three parameters largely impact the TFP growth of innovating firms, as in the equation (10), as well as the decision of whether or not innovate. Therefore, the previous regressions can be used to estimate. After solving the policy functions of firms and aggregate variables that guarantee the market clearing conditions and balanced trade condition, I run a simulation to replicate the regression in Table 3 column (1) and (4). The result confirms $\beta > 1$, and $\theta > 0$, in line with the literature.

5.3 Model fit

Table 4 reports the targeted moments in the model and the data. The model matches well all the empirical targets. Specifically, it replicate well the correlation between TFPR, TFPQ, export and innovation participation; as well as the fraction of firms conducting each activities. It also replicate the regressions well.

Furthermore, we can consider several non-targeted moments, such as TFPR and TFPQ among different groups. These moments are matched well to the data, as Table 5 shows.

6 Counterfactual Analysis

In this section, I compare the baseline model to multiple counterfactual economies. First, I explore the gains from trade in the benchmark and compare them to the case where there are no distor-

Table 5: Non-Targeted Moments

Moment	Data	Model	Data	Model
	Domestic only		*Domestic R&D*	
St. TFPQ	1.25	1.22	1.28	1.20
St. TFPR	0.94	0.92	0.94	0.70
corr(TFPR,TFPQ)	0.91	0.89	0.86	0.85
	Export only		*Export R&D*	
St. TFPQ	1.19	1.21	1.21	1.16
St. TFPR	0.90	0.91	0.82	0.72
corr(TFPR,TFPQ)	0.88	0.88	0.78	0.79

tions. Then I conduct several policy experiments, by moving the distorted baseline economy to an open one with half dispersion of τ, innovation subsidies from the government, and reduction in fixed cost f_i.

6.1 Role of Distortions and the interaction with R&D

In this exercise, I compute several counterfactual economies. First, I shut down trade and take the economy back to autarky by keeping all the parameters except D fixed as in the baseline. Next, I consider a counterfactual efficient economy, where there are no distortions τ, but all other parameters remain the same. Third, I move this efficient economy back to autarky. The results are recorded in Table 6.

Table 6: Comparison to an efficient economy

	Distorted		Efficient	
	closed	open	closed	open
Frac of firms upgrade	6.84%	6.91%	3.64%	3.59%
Avg intensity α	7.95%	8.07%	0.11%	0.11%
Welfare gain	-	1.24%	-	3.06%

When moving the economy from closed to open, there are positive welfare gains under both the distorted case and the efficient case. However, the gains in the distorted economy are considerably smaller in magnitude when contrasted with those in the efficient case.

One noticeable difference lies in how firms are motivated to pursue R&D investment. In the efficient economy, only a small fraction of firms (3.64%) engage in positive R&D. The average investment intensity α across firms is a modest 0.11%, implying innovation is expensive and costly. By contrast, in the distorted economy, subsidies lower the cost of innovation for recipient firms. This enables those firms to opt for greater investment intensity. It also raises the overall fraction of companies choosing to invest in R&D.

When interacting with trade liberalization, the efficient economy sees minimal change in R&D decisions. In fact, the fraction of firms choosing to upgrade decreases slightly. Trade liberalization increases the potential profits from serving the foreign market, but also introduces more competition in the domestic market. These two opposing forces shape firms' profits, and thereby their innovation choices. Given the calibrated parameters, the increased competition outweighs the profit potentials, resulting in a small decrease in the share of firms pursuing R&D investment. The distorted economy sees the opposite. The presence of distortion leads to an increase in average intensity and encourages more firms to pursue technology upgrading under trade liberalization.

We can further decompose welfare to analyze the contribution of the distortion term. As shown in equation (20), there are three components within the distortion term: (1) the selection effect for domestic producers, (2) the selection effect for exporters, and (3) the combined effect of selection and productivity improvements for R&D firms. Table 7 provides the breakdown of how each of these components contributes to the overall welfare impact.

As suggested by BJL, there are two methods for calculating the decomposition. The direct method calculates λ_i and S_i in the open economy, with the three $D \log$ terms computed as the change between the open and closed economies. While easy to compute, this method can introduce inaccuracy since equation (20) is more accurate for small trade cost variations. Instead, the cumulative approach address this issue by integrating compositions from a sequence of small changes in iceberg cost. Specifically, I discretize a large number of trade costs between the benchmark $D = 1.65$ and an extremely large iceberg cost that makes the equilibrium identical to the closed equilibrium. I then sum the changes for each component under any two adjacent D values, using the λ_i and S_i from the lower D. Given the small iceberg cost changes, this cumulative method provides more accurate results.

These two methods yield similar results. The presence of distortion creates overall welfare losses of 15.25% by the direct method and 15.20% by the cumulative method. Of the three components, R&D contributes the most to the losses. This suggests R&D in the distorted economy leads to a further loss, as it encourages wrong firms to grow which worsens the resource misallocation.

Table 7: Decompose of the welfare (in percentage)

	Distorted				Efficient	
	Baseline		No R&D		R&D	No R&D
Gains from trade	1.24		1.40		3.06	3.06
Distortion term decomposition	Direct	Cumulated	Direct	Cumulated		
Overall	-15.25	-15.20	-5.38	-4.97		
Domestic part (1)	-0.58	-0.62	-0.28	-0.29		
Export part (2)	-2.89	-1.67	-5.09	-4.69		
R&D part (3)	-12.78	-12.91	0	0		

Another way to see how R&D further reduces welfare gains is to compare with an economy where firms lack the technology upgrading option, paralleling BJL. Specifically, I make the average fixed cost of R&D f_i extremely large so no firms find R&D investment profitable. As Table 7 shows, this economy has 1.40% trade gains, still far below the efficient economy yet slightly higher than the baseline. Decomposing the distortions reveals selection into exporting now contributes the most losses under both calculation methods, aligning with BJL. When firms can upgrade via R&D, trade liberalization leads to a great fall in aggregate prices, raising welfare gains. However, it generates larger misallocation at the same time, increasing the distortion term. Compared to BJL with no R&D options, the exacerbated resource misallocation outweighs the benefits of the additional price reduction, which yield smaller welfare gains from trade.

One noteworthy observation is that when comparing two efficient economies — one where firms have R&D options and another without — the trade gains are nearly identical. The result is recorded in the last two columns in Table 7. This aligns with prior findings, as the high costs associated with R&D deter firms from choosing to invest in technology upgrades, even when presented with the option.

6.2 Decomposition of aggregate TFP

We can further look into firm side by doing decomposition of aggregate TFP. Though the model cannot speak to the new entrant, , we can still decompose the TFP into between incumbent, exit, and within incumbent by using the equation

$$\Delta Z_t = \underbrace{\sum_{i \in C} \bar{s}_i \Delta z_{it}}_{\text{within firm}} + \underbrace{\sum_{i \in C} \Delta s_{it} \left[\bar{z}_i - Z_{t-k} \right]}_{\text{between firm}} - \underbrace{\sum_{i \in X} s_{it-k} \left[z_{it-k} - Z_{t-k} \right]}_{\text{exit}}$$

where Z_t is the aggregate TFP, z_{it} is firm i productivity, s_t is the output share, $\bar{z}_i, \bar{s}_i$ are the average values between two periods. Figure 1 shows the decomposition when move the distorted economy from autarky to the baseline. Not surprisingly, most of the contribution comes from *within-firm*. The *between-firm* contributes negatively to the aggregate TFP, suggesting the resources do not reallocate to more productive firms. In advance countries or in the efficient counterfactual, this is the most important source of productivity improvement, and the within-firm productivity growth should be less important. The general pattern of the decomposition is similar to what Brandt et al. (2020) find from Chinese data, though the numbers are not exactly the same, further valid the setting of the model.

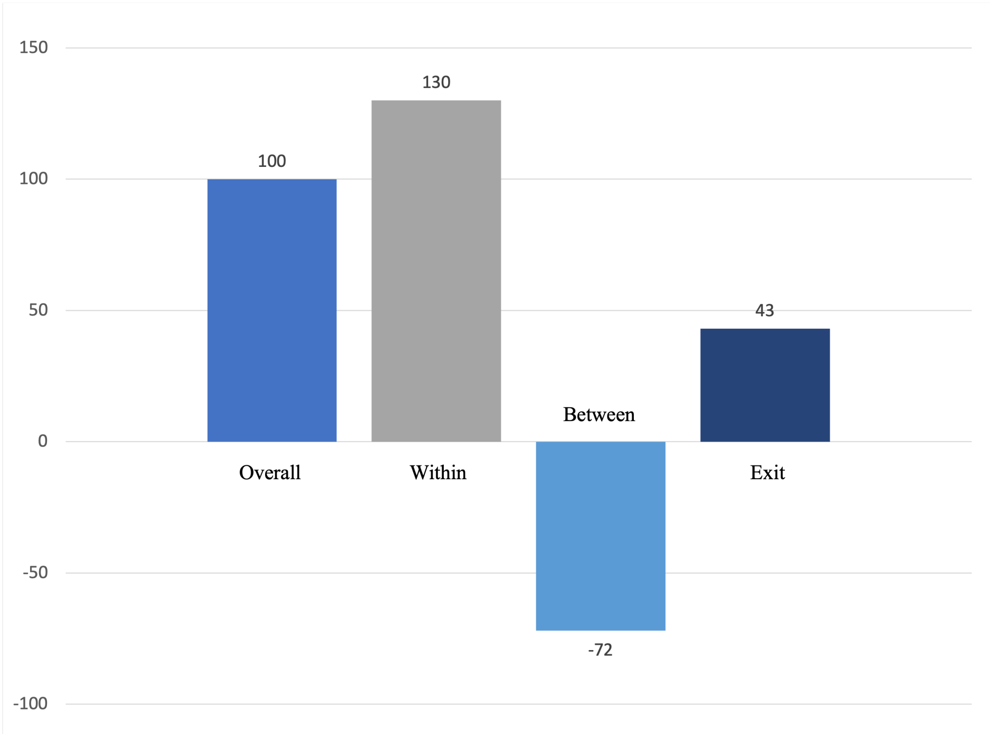
6.3 Policy experiments

Next, I test three related policies to see which can helps the economy to gain more from trade. To do this, I move the distorted economy from autarky to each of the specified counterfactual economies, with D and the remaining parameters held constant at baseline levels.

The first experiment represents the government's effort to reduce distortions at the same time of implementing trade reform and liberalization. Specifically, I reduce the dispersion of the distortions σ_τ by a half. The second experiment focuses on the government's emphasis on supporting R&D. In this scenario, the government is considering a revenue-neutral R&D subsidy program aimed at correcting distortions in innovation decisions. In particular, I set A, the parameter in the innovation cost function $A\alpha^\beta z^\theta$ to be

$$A_2 = A\tau_A(z)$$

Figure 1: Decomposition of TFP: from autarky to the baseline



where A has the same value as the baseline. $\tau_A(z)$ is a function that decreases with firms' productivity z[5], and the mean of τ_A is normalized to 1. This experiment helps us understand whether the government should subsidize R&D before addressing the current distortions during trade liberalization. In the last experiment, I investigate whether a reduction, for instance, 50%, in the R&D fixed cost f_i can contribute. The results are summarized in Table 8.

Table 8: Policy experiments

	Closed	Baseline	(1) 50% σ_τ	(2) targeted R&D subsidy	(3) 50% f_i
Frac of firms upgrade	6.84%	6.91%	8.06%	7.57%	8.77%
Avg intensity α	7.95%	8.07%	2.07%	6.94%	8.72%
Welfare gains	-	1.24%	22.27%	1.29%	1.27%

Among all three experiments, the first one that directly address misallocation is the most

[5]Specifically, I take $\tau_A(z) = z^{-1/2}$ for each of the z on the grid and re-normalize the mean across the distribution G to be 0. It turns out after solving the equilibrium, the government balance regarding R&D subsidy is small, near to zero.

efficient. It improves the selection mechanisms for domestic production and export, and correct the distortions in R&D decisions at the same time. As a result, more firms, especially those who are productive but heavily taxed firms, now adopt new technology. Even though they choose smaller intensity, there is still a substantial increase in the welfare and aggregate TFP.

Additional R&D subsidies lead to a slight improvement in welfare gains. It helps productive firms to upgrade technology, as reflected in the increased fraction of firms actively pursuing R&D. It reduces the average intensity at the same time, since it discourage those previously subsidized firms from expanding. Nevertheless, this policy has limited impact on welfare and aggregate TFP as the distortion in production persists. As productive firms continue to face taxation, resulting in diminished profits, the incentive to engage in R&D remains too low. Providing them with only reduction in R&D costs does not generate substantial assistance. Similar logic applies when reducing the fixed cost f_i.

7 Conclusion

This paper evaluates the aggregate TFP and welfare gains from trade in an economy with firm-level distortions. Different from previous studies, this paper introduces an additional channel in which firms can invest in R&D and enhance their current productivity. Though many studies have found that technology improvement can be another source of gains from trade, it becomes evident that under the distortions, technology improvement does not significantly contribute to the overall welfare gain. This is because under the misallocation, both the between-firm allocation efficiency and the within-firm technology improvement are distorted. When the economy opens up to trade, both welfare and aggregate TFP gain could be largely offset as trade exacerbates the resource allocation, and fosters less suitable firms to grow. The quantitative analysis confirms the mechanism. The results emphasize the importance of structural reform. Other policies, such as R&D subsidies or reductions in fixed costs, enhance the within-firm channel, but given the persisting issues in the between-firm channel, their impact on welfare gains remains limited.

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Appendix

A Equilibrium of the baseline model

Intermediate firms in Home take aggregate price P, P^*, w, and aggregate demand Q, Q^* as given. Based on the assumption of constant markup, firms with status $s = (z, \tau, c_x, c_i)$ set price as

$$p(s) = \frac{\sigma}{\sigma - 1}\frac{w\tau}{z'(s)}, \quad p_x(s) = \frac{\sigma}{\sigma - 1}\frac{w\tau D}{z'(s)}$$

where the technology $z'(s)$ is the policy function of optimal R&D intensity. The demand from domestic and foreign final good firms are

$$q(s) = \left(\frac{p(s)}{P}\right)^{-\sigma} Q, \quad q_x(s) = \left(\frac{p_x(s)}{P^*}\right)^{-\sigma} Q^*$$

A firm with status s first decide operate in domestic market or not, with the related profit in equation (5) as

$$\pi_d(s) = \Pi_d z^{\sigma-1}\tau^{-\sigma} - f_d$$

If the status generates positive profit, then the firm enters the market. Next, this firm decide whether to engage in export and R&D investment by comparing the potential profits regarding to export only, domestic only but upgrade technology, and export as well as upgrade technology, as shown in (7), (8), (9)

$$\begin{aligned}
\pi_x(s) &= \Pi_x D^{1-\sigma} z^{\sigma-1}\tau^{-\sigma} - c_x f_x \\
\pi_d^i(s) &= \Pi_d z^{\sigma-1}\tau^{-\sigma}\alpha_1(s) - A\alpha_1(s)^\beta z^\theta - c_i f_i \\
\pi_x^i(s) &= \Pi_x D^{1-\sigma} z^{\sigma-1}\tau^{-\sigma} + (\Pi_d + \Pi_x D^{1-\sigma}) z^{\sigma-1}\tau^{-\sigma}\alpha_2(s) - A\alpha_2(s)^\beta z^\theta - c_i f_i - c_x f_x
\end{aligned}$$

where $\Pi_d = \frac{P^\sigma Q}{\sigma^\sigma(\sigma-1)^{1-\sigma}}$, $\Pi_x = \frac{P^{*\sigma} Q^*}{\sigma^\sigma(\sigma-1)^{1-\sigma}}$ are same to all firms, optimal R&D intensities without and with exporting investment are

$$\alpha_1(s) = \left(\frac{\Pi_d \tau^{-\sigma} z^{\sigma-1-\theta}}{\beta A}\right)^{\frac{1}{\beta-1}}$$
$$\alpha_2(s) = \left(\frac{(\Pi_d + \Pi_x D^{1-\sigma})\tau^{-\sigma} z^{\sigma-1-\theta}}{\beta A}\right)^{\frac{1}{\beta-1}}$$

A firm with status s therefore has following total profit

$$\pi(s) = \pi_d(s) + \max\{0, \pi_x(s), \pi_d^i(s), \pi_x^i(s)\}$$

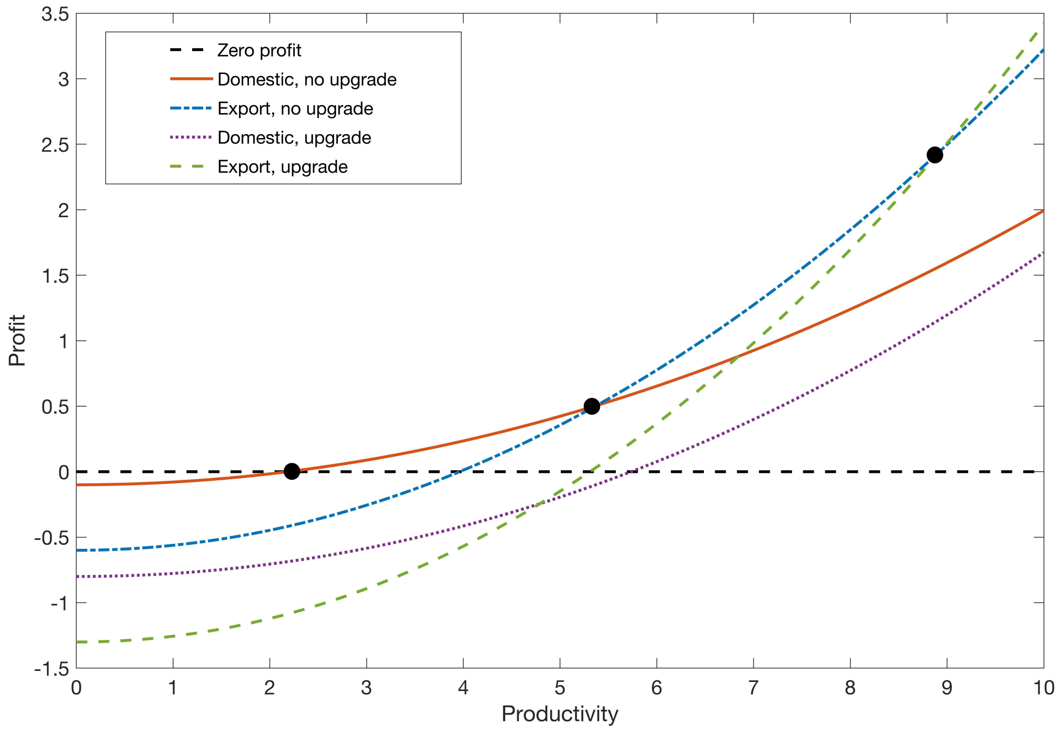
Despite of the heterogeneity in fixed costs, this model produces similar productivity cutoffs for firms. Controlling the fixed costs and output wedge τ, the lowest productivity firms exit the market, highest productivity firms engage in both exporting and R&D investments. In the middle range of productivity, depends on the shape of profit functions, three different cases could happen: (1) export only, (2) domestic only but with technology upgrading, (3) $\pi_d^i(s), \pi_x(s)$ both smaller than $\pi_d(s)$, so firms transit directly from domestic only, to export and R&D. Fig 2 shows the first case under certain value of parameters.

Total expected profit for a firm about to enter is the aggregation of profits across all possible states s, including those lead to a immediate exit. The free entry condition leads to:

$$\int_s \pi(s) dG(s) = f_e$$

Solving firm's problem by taking aggregate variables as given, we have all the policy functions regarding to price, quantity, export participation, R&D participation, R&D intensity, and labor used, for both Home and Foreign. The remaining 7 unknowns are $P, P^*, Q, Q^*, M, M^*, w^*$. By using 2 free entry conditions, 2 market clearing conditions, trade balance, and 2 aggregate price equations, we can fully solve the equilibrium.

Figure 2: Profit of a given level of τ



B Proof for Propositions

B.1 Proposition 2

With homogeneous productivity, $f_d = f_x = f_i = 0$, all firms export and engage in innovation. But since they differ in the output wedge, the optimal intensity α each firm chooses is different. This setting therefore removes selection, and only keeps the heterogeneity in within-firm innovation effort. Based on the assumption, define $h = 1/\tau$ which follows a Pareto distribution with parameter θ, the optimal intensity α for a firm with h is determined by solve the following problem

$$\max_{\alpha}\{(1 + D^{1-\sigma})\Pi_d h^{\sigma}\alpha - A\alpha^{\beta}\}$$

where $\Pi_d = \frac{P^\sigma Q}{\sigma^\sigma(\sigma-1)^{1-\sigma}}$. As before, more subsidized firm will choose higher intensity

$$\alpha(h) = \left[\frac{(1+D^{1-\sigma})\Pi_d h^\sigma)}{A\beta}\right]^{\frac{1}{\beta-1}}$$

Firm's profit

$$\pi(h) = (1-\frac{1}{\beta})(A\beta)^{\frac{1}{1-\beta}}\left((1+D^{1-\sigma})\Pi_d\right)^{\frac{\beta}{\beta-1}} h^{\frac{\theta\beta}{\beta-1}}$$

Next consider the free entry condition and labor market clearing condition. As h is Pareto distributed, the two equations can be derive as the following

$$\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma} + (1-\frac{1}{\beta})\frac{(A\beta)^{\frac{1}{1-\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma} = f_e$$

$$(\sigma-1)\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma} + ((\sigma-1)+\frac{1}{\beta})\frac{(A\beta)^{\frac{1}{\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma} + f_e = \frac{L}{M}$$

Combine these two, the key equation of the firm total mass M has the expression:

$$M = \frac{L}{\sigma}\left[\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma} + \frac{(A\beta)^{\frac{1}{1-\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma}\right]^{-1}$$

Now consider the distortion term in the welfare equation, which has the expression

$$\begin{aligned}PQ &= \sigma M\left[\int(1+D^{1-\sigma})\Pi_d h^{\sigma-1}dG + (A\beta)^{\frac{1}{1-\beta}}\int(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,h^{\frac{\beta}{\beta-1}(\sigma-1)}dG\right]\\ &= \sigma M\left[\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma+1} + \frac{(A\beta)^{\frac{1}{1-\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma+1}\right]\end{aligned}$$

Since now all firms export, λ_1 and λ_2 defined in Proposition 1 or equation (20) can be combined together as λ. Similarly, combine S_1 and S_2 together, and define it as S:

$$\lambda = \frac{(1+D^{1-\sigma})\Pi_d}{(1+D^{1-\sigma})\Pi_d + \frac{\theta-\sigma+1}{\theta-\frac{\beta}{\beta-1}\sigma+1} conq \cdot \Pi_d^{\frac{\beta}{\beta-1}} (1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}$$

$$S = \frac{(1+D^{1-\sigma})\Pi_d}{(1+D^{1-\sigma})\Pi_d + \frac{\theta-\sigma}{\theta-\frac{\beta}{\beta-1}\sigma} conq \cdot \Pi_d^{\frac{\beta}{\beta-1}} (1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}$$

Note that $\lambda = 1 - \lambda_3$ and $S = 1 - S_3$, where λ_3 is the share of addtional output produced due to technology upgrading, and S_3 is the additional labor input used in production due to technology upgrading.

Then $d\log(PQ)$ with an small decrease in iceberg trade cost is

$$\begin{aligned} d\log(PQ) =& d\log\left(\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma+1} + \frac{(A\beta)^{\frac{1}{1-\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma+1}\right) \\ & - d\log\left(\frac{(1+D^{1-\sigma})\Pi_d}{\theta-\sigma} + \frac{(A\beta)^{\frac{1}{1-\beta}}\,\Pi_d^{\frac{\beta}{\beta-1}}\,(1+D^{1-\sigma})^{\frac{\beta}{\beta-1}}}{\theta-\frac{\beta}{\beta-1}\sigma}\right) \\ =& \frac{1}{\beta-1}(S-\lambda)d\log\Pi_d + \frac{(\sigma-1)D^{1-\sigma}}{1+D^{1-\sigma}}\left(1-\frac{\beta}{\beta-1}\right)(S-\lambda)d\log D \end{aligned}$$

Or equivalently

$$d\log(PQ) = -\frac{1}{\beta-1}(S_3-\lambda_3)\Big(\Delta\log(\Pi_d) + \Delta\log(1+D^{1-\sigma})\Big)$$

From the free entry condition, trade cost reduction lead to decrease in Π_d, hence $d\log\Pi_d > 0$. It is easy to see $S_3 > \lambda_3$. Therefore the misallocation term is always negative. Q.E.D.

B.2 Proposition 3

This proposition assumes (1) all firms innovate at same δ if they choose to upgrade; (2) firms only differ in the output wedge τ, and $h = \frac{1}{\tau}$ follows Pareto distribution with parameter θ; (3) $0 < f_d < f_x < f_i$. Then same as BJL and Bustos (2011), there is a clear order: firms with smallest h exit directly; as h becomes larger, firms become domestic only, then exporter, then engage in both exporter and upgrading. The cutoffs of exit, export and upgrading are

$$\bar{h}_d = \left(\frac{f_d}{\Pi_d}\right)^{\frac{1}{\sigma}}$$
$$\bar{h}_x = \left(\frac{f_x}{f_d D^{1-\sigma}}\right)^{\frac{1}{\sigma}} \bar{h}_d$$
$$\bar{h}_i = \left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{\frac{1}{\sigma}} \bar{h}_d$$

This setting only keeps the selection, and removes the heterogeneity in within-firm innovation.

Combining the free entry condition and labor market clearing condition, equation (18) has the following expression:

$$\frac{L}{\sigma M} = \int_{\bar{h}_d} \Pi_d h^\sigma \, dG(h) + D^{1-\sigma} \int_{\bar{h}_x} \Pi_d h^\sigma \, dG(h) + (1+D^{1-\sigma})\delta \int_{\bar{h}_i} \Pi_d \, dG(h)$$

Or

$$\frac{L}{\sigma M} = \frac{f_d \left(\frac{f_d}{\Pi_d}\right)^{-\frac{\theta}{\sigma}}}{\theta - \sigma} \left(1 + \frac{f_x}{f_d}\left(\frac{f_x}{f_d D^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}} + \frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}\right)$$

At the same time, the free entry condition

$$\int_{\bar{h}_d} \Pi_d h^\sigma \, dG(h) + D^{1-\sigma} \int_{\bar{h}_x} \Pi_d h^\sigma \, dG(h) + (1+D^{1-\sigma})\delta \int_{\bar{h}_i} \Pi_d \, dG(h) - \left[f_d \int_{\bar{h}_d} dG(h) + f_x \int_{\bar{h}_x} dG(h) + f_i \int_{\bar{h}_i} dG(h)\right] = f_e$$

gives us

$$\left(\frac{f_d}{\Pi_d}\right)^{-\frac{\theta}{\sigma}} \left(1 + \frac{f_x}{f_d}\left(\frac{f_x}{f_d D^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}} + \frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}\right) = f_e \frac{(\theta-\sigma)\theta}{\sigma}$$

therefore M is a constant, and

$$\log(\left(1 + \frac{f_x}{f_d}\left(\frac{f_x}{f_d D^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}} + \frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}\right)) - \frac{\theta}{\sigma}\log(\frac{f_d}{\Pi_d}) = 0$$

The total expenditure equation (16) has the following expression under Pareto distribution:

$$PQ = \sigma M\left[\frac{f_d\left(\frac{f_d}{\Pi_d}\right)^{-\frac{\theta+1}{\sigma}}}{\theta+1-\sigma}\left(1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}\right)\right]$$

Now the definition of output share $\lambda_1,\ _2,\ \lambda_3$ and input share $S_1,\ S_2,\ S_3$ are:

$$\lambda_1 = \frac{1}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}}$$

$$\lambda_2 = \frac{\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}}$$

$$\lambda_3 = \frac{\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}}$$

$$S_1 = \frac{1}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}}$$

$$S_2 = \frac{\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}}}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}}$$

$$S_3 = \frac{\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}}{1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}}$$

The change of distortion term with respect to a small trade shock is therefore:

$$\begin{aligned}
d\log(PQ) =& d\log(\left(1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}\right)) \ - \ \frac{\theta+1}{\sigma}d\log(\frac{f_d}{\Pi_d}) \\
=& d\log(\left(1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta+1}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta+1}{\sigma}}\right)) \\
&-\frac{\theta+1}{\theta}d\log(\left(1+\frac{f_x}{f_d}\left(\frac{f_x}{f_dD^{1-\sigma}}\right)^{-\frac{\theta}{\sigma}}+\frac{f_i}{f_d}\left(\frac{f_i}{f_d(1+D^{1-\sigma})\delta}\right)^{-\frac{\theta}{\sigma}}\right))
\end{aligned}$$

Plug in λ_i and S_i

$$d\log(PQ) = \frac{\sigma - 1}{\sigma}(\theta + 1)\left[(S_2 - \lambda_2) + \frac{D^{1-\sigma}}{1 + D^{1-\sigma}}(S_3 - \lambda_3)\right]\Delta \log D$$

Note that we only know $\lambda_1 > S_1$, therefore whether $d\log(PQ)$ is negative or positive depends on the relative size of $\frac{\lambda_2}{S_2}$ and $\frac{\lambda_3}{S_3}$. Q.E.D

C Computational Details

For any guess of the set of parameters, I first generate the grids for z, τ, $\bar{c}_i$. These grids span $\pm$ 5 standard deviations for each variable, accompanied by two $0/1$ vectors indicating whether the firm is permitted to export and innovate. Then I produce the probability of drawing status on each grid based on the assumed distribution G. To attain equilibrium under the specified parameters, I employ the following algorithm:

(1) Define term of trade $u = \frac{P^{*\sigma}Q}{P^{\sigma}Q}$, guess u

(2) With the guess of u, find Π_d, as it is the fixed point of free entry condition. Similarly, solve Π_d^*/w^* for Foreign

(3) Use the definition of u, Π_d, Π_d^*/w^* to solve w^*, and use labor market clearing conditions to obtain total firm mass $M,\ M^*$. Plug them to balanced trade condition, and generate an update of u

(4) Iterate, until u converges.

After solving the equilibrium, I conduct a simulation by generating 10^7 points according to the established distribution, with each entry positioned on a grid. I then apply the policy functions from the preceding step to compute the moments. Next, I compare these simulated moments with the actual data, and accordingly refine the initial parameter estimates.

D Data and Additional Empirical Result

The literature addressing trade liberalization in developing countries has identified alternative channels, such as the utilization of intermediate inputs, as evidenced by Goldberg et al. (2010) for India and Amiti and Konings (2007) for Indonesia. With reduction of trade cost, firms benefit from the increased access to previously unavailable inputs, and better quality of inputs. This section seeks to test this hypothesis using Chinese data.

D.1 Additional Data

To examine how the input tariff reduction leads to increasing use of intermediate input, as well whether it promotes productivity growth and technology adoption, I incorporate two additional sets of data. The first one is the China's General Administration of Customs, providing HS 8-digit product transaction-level trade data for each firm when exporting to and importing from other countries The second one is TRAINS from United Nations Conference on Trade and Development (UNCTAD), which collects HS 6-digit product-level tariff data for each pair of trading partners.

The Chinese custom data and the manufacturing firm survey are collected separately, each assigned distinct system ID numbers. To establish a connection between them, I adopt the methodology proposed by Wang and Yu (2013). Initially, I match firms based on their Chinese name and the corresponding year. To increase the matches, I then use postal code and 7 last digit of phone numbers. Specifically, I focus on imports originating from ordinary trade and confined within the manufacturing sectors to eliminate pure assembly, given the substantial presence of processing trade in China. Moreover, to exclude trading intermediaries, firms with names containing any Chinese characters indicating "Trading Company" or "Importing and Exporting Company" are excluded from the analysis.

Regarding tariffs, they are documented at the HS 6-digit product level for each trading partner after join WTO. Consequently, the available data for China spans from 2001 to 2007. To mitigate potential endogeneity issues arising from firms' future imports and import tariff reductions, I harmonize the HS system by mapping it to the Chinese GB/T 4-digit sector code. I then calculate the average import tariff for each sector. Additionally, to prevent endogeneity concerning different trading partners, I employ the trading partner's GDP as a weight when computing the sector's average import tariff. This same process is applied to export tariffs, representing tariffs imposed by trading partners on Chinese exports.

D.2 Results

Table 9 records how input tariff reduction lead to increase use of imported input. The dependent variables in the regressions are the import value in Columns (1)-(2) and the count of different HS 6-digit products imported in Columns (3)-(4), both in log term. When regressed against the last period import tariffs, the results indicate a deviation from prior literature. Contrary to expectations, a reduction in input tariffs does not result in an increase in the value or variety of imports, even when accounting for firm fixed effects (Column (1) and (3)). When adding more controls such as last period export tariffs, firm distortion TFPR, productivity TFPQ, as well as the participation in export and R&D, and with fixed effect on sector and year, the results remain the same (Column (2) and (4)).

Table 10 shows the result of firm outcomes. The dependent variable for Columns (1)-(2) is log output, for Columns (3)-(4) is TFP growth, and for Columns (5)-(6) is R&D expenditure. I regress each dependent variable within firms and within sectors, accounting for firms' characteristics. Similar to the findings in Table (9), the reduction in import tariffs does not show a significant contribution to firm outcomes. In the study by Mo et al. (2021), the authors differentiate between capital and intermediate imports, discovering that it is capital imports that generate dynamic effects and promote future R&D specifically within the context of China. Given that capital goods imports are often considered a conduit for international technology diffusion, this paper underscores an intriguing extension by exploring another potential source of gains from trade: technology spillover and diffusion.

Table 9: Input Tariffs and Firm Imports

	(1) log(Import Value)	(2) log(Import Value)	(3) log(Import Variety)	(4) log(Import Variety)
Import tariff	0.003	-0.005	0.001	0.004$^{\cdot}$
	(0.003)	(0.006)	(0.001)	(0.002)
Export tariff		-2.00***		-0.024***
		(0.016)		(0.005)
log(TFPQ)		1.81***		0.62***
		(0.034)		(0.011)
log(TFPR)		-2.20***		-0.80***
		(0.047)		(0.015)
1(R&D)		0.28***		-0.017
		(0.054)		(0.017)
1(EXP)		-0.69***		0.063***
		(0.047)		(0.015)
Firm FE	Y	N	Y	N
Prov,Ind FE	N	Y	N	Y
Year FE	Y	Y	Y	Y
R-squared	0.90	0.30	0.90	0.33
obs	62,737	17,713	62,737	17,713

Table 10: Input Tariffs and Firm Outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
	Output	Output	TFP growth	TFP growth	R&D	R&D
Import tariff	0.002***	0.000	-0.001	-0.002*	0.005*	0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.001)
Export tariff	0.002*	-0.020***	-0.005*	0.005***	0.002	-0.007***
	(0.001)	(0.001)	(0.003)	(0.002)	(0.004)	(0.002)
log(TFPQ)		1.700***		-0.071***		0.619***
		(0.003)		(0.004)		(0.005)
log(TFPR)		-1.886***		-0.052***		-0.736***
		(0.002)		(0.006)		(0.007)
1(R&D)		0.142***		0.030***		3.554***
		(0.004)		(0.008)		(0.009)
1(EXP)		0.020***		-0.018***		0.163***
		(0.003)		(0.006)		(0.007)
Firm FE	Y	N	Y	N	Y	N
Prov,Ind FE	N	Y	N	Y	N	Y
Year FE	Y	Y	Y	Y	Y	Y
R-squared	0.93	0.72	0.32	0.03	0.81	0.44
obs	783,471	358,455	493,372	147,563	515,599	358,426