Misallocation Under Trade Liberalization

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Abstract

What is the impact of trade liberalization on economies with sizeable distortions? A Melitz model incorporating firm-level wedges shows that trade liberalization can exacerbate rather than improve resource allocation, causing a decline rather than a rise in TFP. We derive a theoretical decomposition of the various channels through which distortions impact the effects of trade, and show that trade can engender welfare losses. A quantitative assessment using Chinese manufacturing data shows that there is a TFP loss in association with trade liberalization, and a significantly smaller gains to trade than what is implied by standard formulations. Moreover, using only aggregate statistics to measure gains to trade apropos the ACR formula would lead to markedly different predictions.

Keywords: Capital and labor wedges, misallocation, trade liberalization, gains from trade, industrial policy

JEL classification: E23 F12 F14 F63 L25 O47

1 Introduction

The question of how much developing countries benefit from opening up to goods trade is a time-honoured subject, both of practical import and intellectual interest. Much has been understood about the nature and type of gains to trade, thanks to the remarkable progress made in the field of international trade in recent decades. On the empirical front, countries' experiences with trade have been of a mixed lot (Levine and Renelt (1992), Tybout (1992)).

One issue relevant for developing economies that have been largely set aside so far is the prevalence of distortions and whether they interact with trade to affect aggregate productivity. Distortions are sizeable and ubiqutous— taxes and subsidies, implicit guarantees and bailouts, preferential access to land and capital, industrial policy and export promotion are among the many examples. In influential work, Hsieh and Klenow (2009) show that these distortions can induce a significant misallocation of resources across firms, causing a reduction in aggregate productivity.

If one of the hallmarks of the new trade theory is to show that above and beyond effects of increased variety and scale, productivity gains arising from a more efficient allocation of resources constitute an important gains to trade, then a natural question would be whether trade can potentially reduce the TFP losses associated with distortions. We endeavor to provide an answer to this question using the discipline of a general equilibrium model of trade that also incorporates idiosyncratic firm-level distortions. We then turn to firm-level data from China to conduct empirical investigations as well as quantify welfare and productivity changes.

A main conclusion is that contrary to the mechanism highlighted in the Melitz model, where trade induces a reallocation of resources from low productivity to high productivity firms, trade liberalization in the presence of distortions can induce the opposite— exacerbate rather than mitigate the inefficient allocation of resources. The reason is simple: distortions (for instance, tax and subsidies) act as a veil to a firm's true productivity. A firm may be producing in the market not because it is inherently productive, but because it is sufficiently subsidized. There will be a mass of highly-subsidized but not adequately productive firms who will export and expand, at the cost of other more productive firms. The high productivity/ high tax firms which were marginally able to survive in the domestic market would be driven out as the other firms gain market share and drive up costs. In other words, the selection effect which engendered efficiency gains in the Melitz model is no longer based solely on productivity; it is now determined jointly by firm productivity and distortions. Trade may thus *lower* the average productivity of firms.

Importantly, the correlation between productivity and distortions, as well as the dispersion in distortions, will matter for the size of the gains and losses of trade. We show that empirically, the two variables display a strong and positive relationship—that is, more productive firms are also subject to higher taxes. This tends to dampen/increase the trade gains/losses. Another point we stress in this paper is that the 'misallocation of resources' goes beyond the observed misallocation among a set of operating firms. There is also a plausible misallocation among potential entrants and operating firms– firms that should have entered the market in an efficient economy that couldn't, and firms that should have otherwise exited but have not.

In Melitz and Redding (2015), the endogenous margin of adjustment along the entry/exit the domestic and export markets presents itself as an efficient mechanism that brings about an additional source of gains to trade. Adjusting the set of firms selected for production and exports increases average productivity and yields higher welfare. It is this very mechanism in our model that actually brings about a *reduction* in efficiency and welfare. We show that theoretically, this unobserved misallocation can be large and more important than the misallocation among a given set of observable firms.

Our modelling framework incorporates firm-specific distortions into a two-country Melitz model. There are two dimensions of heterogeneity at the firm-level: productivity and distortions. These distortions are assumed to be exogenous output wedges or factor wedges, following Hsieh and Klenow (2009), henceforth HK. They drive differences in the marginal products across firms. Different from HK, however, our model allows for firm entry and exit, and international trade. The endogenous mechanism of entry and selection is crucial in our setting and what can bring about efficiency losses associated with trade.

The paper makes three contributions. First, it provides a theoretical decomposition of the trade impact on aggregate productivity, determined by the measure of firms (variety), and the average productivity of firms. Trade can lower aggregate productivity by lowering the average productivity of firms. Intuitively, this arises if some high productivity/high tax firms exit, while some low productivity/high subsidy firms survive and/or gain market share. We show precisely how the existence of distortions changes the cutoff function for firm production/exports, how it changes the measure of firms as well as a aggregate demand—all of which affect entry and selection. How large the negative impact will come from trade will depend on the correlation between firm-distortions and productivity, as well as the dispersion of distortions across firms. We show that even when this correlation is negative trade losses can occur.

Second, we conduct an empirical investigation. Although the study can apply to any group of countries, we focus on Chinese manufacturing data for the simple reason that this country is well known for its prevalent State interventions and policies; it is also the case that trade liberalization has been an important recent phenomenon. The exercise is also well-suited to compare with HK's findings on how distortions affect aggregate productivity for China—-with the addition of endogenous firm selection and trade. Using firm-level data, we measure wedges in capital, labor and trade costs. We show that there is a robust relationship between a firm's wedges and its productivity, that a significant variation of these wedges are accounted for by productivity differences, and that these wedges are also correlated to firm characteristics such as ownership (state, private, foreign) and age.

A noteworthy point is that this observed positive correlation cannot be treated as *the* underlying correlation, as the measured correlation is determined by a combination of a selection mechanism *and* the underlying correlation. Intuitively, a higher taxed firm has to be more productive in order to survive or export. This is the endogenous selection mechanism at work. A second determinant is the underlying correlation, which matters for quantitative estimates of welfare and efficiency gains to trade. This brings us to two related works. Costa-Scottini (2018) and Ho (2010) introduce firm-level distortions into a model of trade. The main difference between these works and ours is that there are always gains to trade predicted by their model. Both assume a perfect correlation of (log) productivity and (log) wedges. Hence, firm profits still sort perfectly according to firm productivity. There are always TFP/welfare gains moving from a closed to open equilibrium because resources move from high marginal cost to low marginal cost firms. More importantly, this counters what we find in the data in that 1) measured (log) productivity and (log) wedges are far from perfectly correlated, and 2) exporters have lower wedges—as predicted by our model and consistent with its selection mechanism. As long as these two variables are not perfectly correlated, selection will affect their measured correlation and one would need to estimate it from the model. For this reason, a careful estimation of the joint distribution of productivity and wedges based on a structural model and firm-level data is imperative to obtaining the correct quantitative results. It brings about dramatically different conclusions, as our quantitative analysis demonstrates.

Lastly, we use our estimated model to quantify the impact of trade on welfare and aggregate productivity. Domestic frictions affect the trade effects on welfare, aggregate productivity and misallocation. We use both our theoretical decomposition (for local changes in trade cost) and run counterfactual experiments to compute the TFP and welfare effects of trade liberalization. We also run counterfactual experiments for domestic reforms. Our main conclusion is that the trade gains are much smaller when taking into account distortions; that there is a TFP loss of 3% as opposed to a TFP gain of 13.3% in the case without distortions.

One may wonder whether in this context exporters are necessarily on average less productive than non-exporters. The answer is that conditional on taxes/subsidies, exporters are still more productive than non-exporters for the same reason that the exporting cost is still higher. On average, exporters can be more or less productive than non-exporters depending on the parameters. However, the average productivity of all firms can be lower under trade than in a closed-economy equilibrium in either of these cases.

There is little controversy over the fact that distortions are common— especially in developing countries. Whether they obstruct (or aid) the well-accepted advantages of trade is a question worthy of investigation. In the case of China, distortions are widely prevalent, as well as varied in form. State owned enterprises enjoy privileges over private firms; more connected private firms enjoy benefits over others. These implicit subsidies could take the form of soft budget constraints, low costs of capital, preferential tax treatments and implicit guarantees. Also, banks are more ready to lend to large firms, SOEs, firms with connections resulting from asymmetric information and risk aversion of state-owned banks. An inefficient financial system largely dominated by banks coupled with vast administrative capacities in decision-making inevitably affect resource allocation. Our empirical analysis provides supportive evidence to some of these accounts of distortions. We also address the issue of measurement error, and use three alternative approaches using panel data to show that measurement error accounts for little of the dispersion in marginal products across firms.

In this paper, we focus on wedges at the firm-level. These distortions are most likely important also at the sectoral level. They may impact patterns of trade and gains to trade as well as international spillovers. This traces back to an older literature (Bhagwati and Ramaswami (1963)) that illustrates some of these theoretical implications, absent quantitative studies. As subsidies span the gamut of sectors beyond manufacturing, presently available data may not be well-suited to identify the wedges across sectors. With greater availability of data coming on the horizon, we leave that for future research. Given the importance of new theories of trade featuring heterogeneous firms, we focus this current study on trade and resource allocation at the firm-level.

2 Theoretical Framework

The world consists of two large open economies. In each country i, there is a measure L^i of identical consumers. The two economies can differ in population, L, which is immobile across countries and inelastic in supply.

Consumers. A representative consumer in the Home country chooses the amount of final goods C in order to maximize utility $u(C)$, subject to

$$PC = wL + \Pi + T,$$

where wL is labor income, Π is dividend income, and T is the amount of lump-sum transfers received from the government.

Final Goods Producers. Final goods producers are perfectly competitive, and combine intermediate goods using a CES production function

$$Q = \left[\int_{\omega \in \Omega} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where σ is the elasticity of substitution across intermediate goods, and Ω is the endogenous set of goods. The corresponding final goods price index is thus

$$P = \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}},$$

where $p(\omega)$ is the price of good ω in the market. The individual demand for this good is thus given by

$$q(\omega) = \frac{p(\omega)^{-\sigma}}{P^{-\sigma}} Q.$$

Intermediate Goods Producers. There is a competitive fringe of potential entrants that can enter by paying a sunk entry cost of f_e units of labor. Potential entrants face uncertainty about their productivity in the industry. They also face a stochastic revenue wedge τ, which can be seen as a tax (>1) or subsidy (<1) on every pq earned. Once the sunk entry cost is paid, a firm draws its productivity φ and τ from a fixed joint distribution, $g(\varphi, \tau)$ over $\varphi \in (0, \infty), \tau \in (0, \infty)$. Productivity and the revenue wedge remain the same after entry, but firms face a constant exogenous probability of death δ, which induces steady-state entry and exit of firms in the model.

Firms are monopolistically competitive. Production of each intermediate good entails fixed production cost of f units of labor and a constant variable cost that depends on firm productivity. The total labor required to produce $q(\varphi)$ units of a variety is therefore: [1]

$$\ell = f + \frac{q}{\varphi}.$$

Productivity φ is idiosyncratic and independent across firms. The existence of a fixed

[1]We can easily extend the production including capital, $k^{\alpha}\ell^{1-\alpha}$. The unit cost for producing q or fixed cost is $\alpha^{-\alpha}(1-\alpha)^{\alpha-1}w^{1-\alpha}r_k^{\alpha}$ where r_k is the rental cost of capital. In our model, we introduce one heterogeneous distortions at the firm level, and our τ includes distortions that increase the marginal products of capital and labor by the same proportion as an output distortion. In the data, there are distortions that affect both capital and labor and distortions that change the marginal product of one of the factors relative to the other. In our quantitative exercises, we include both capital and labor, and the distortions on both factors.

production cost means that only a subset of firms produces—those that draw a sufficiently low productivity cannot generate enough variable profits to cover the fixed production cost. If firms decide to export, they face a fixed exporting cost of f_x units of labor and iceberg variable costs of trade τ_x, which is greater than 1. Firms with the same productivity and distortion behave identically, and thus we can index firms by their (φ, τ) combination.

An intermediate goods firm thus solves the following problem

$$\max_{p,q} \; \frac{pq}{\tau} - \frac{w}{\varphi}q - wf$$

subject to the demand function

$$q = \frac{p^{-\sigma}}{P^{-\sigma}}Q, \tag{1}$$

henceforward suppressing ω for convenience. Firms are infinitesimally small, and thus take the aggregate price index as given. Equating the after-tax marginal revenue with marginal costs yields the standard result that equilibrium prices are a mark-up over marginal costs:

$$p = \frac{\sigma}{\sigma - 1}\frac{w\tau}{\varphi}. \tag{2}$$

Optimal profits are then

$$\pi = \sigma^{-\sigma}(\sigma - 1)^{\sigma-1}P^{\sigma}Q\tau^{-\sigma}w^{1-\sigma}\varphi^{\sigma-1} - wf. \tag{3}$$

It immediately follows that given the fixed cost of production, there is a zero-profit cutoff productivity below which firms would choose not to produce, and exit the market. Thus, a firm would choose to produce only if $\varphi \geq \varphi^*(\tau)$. This cutoff productivity level satisfies

$$\varphi^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1}\left[\frac{wf}{P^{\sigma}Q}\right]^{\frac{1}{\sigma-1}} w\tau^{\frac{\sigma}{\sigma-1}}. \tag{4}$$

The cutoff productivity is now a function of the firm-specific distortion, and differs across firms facing different levels of distortions. Firms with a higher tax τ will have a higher cutoff for productivity. This means that low productivity firms that would have been otherwise excluded from the market can now enter the market and surivive if sufficiently subsidized.

Finally, the government's budget is balanced so that

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

where Σ is the endogenous set of home products.

2.1 Closed Economy Equilibrium

The steady-state industry equilibrium features a constant mass of firms entering and producing, along with a stationary ex-post distributions of productivity and taxes among operational firms. With a constant level of productivity fixed upon entry, and a constant independent probability of firm death δ, the stationary ex-post distribution for productivity and taxes is a truncation of the ex-ante productivity-tax distribution, $g(\varphi, \tau)$, at the zero-profit cutoff productivity given by Eq.4:

$$\mu(\varphi, \tau) = \frac{g(\varphi, \tau)}{\int_0^\infty \int_{\varphi^*(\tau)}^\infty g(\varphi, \tau)\, d\varphi d\tau} \tag{5}$$

if $\varphi \geq \varphi^*(\tau)$; and 0 otherwise. The denominator is the probability of successful entry, denoted as

$$\omega_e = \int_0^\infty \int_{\varphi^*(\tau)}^\infty g(\varphi, \tau)\, d\varphi d\tau. \tag{6}$$

In an equilibrium with positive entry, the free entry condition equates the expected value of entry with the sunk entry cost (in terms of labor), so that

$$\omega_e \sum_{s=0}^{\infty} (1-\delta)^s E[\pi(\varphi, \tau)] = \omega_e \frac{E[\pi(\varphi, \tau)]}{\delta} = w f_e, \tag{7}$$

where the per-period expected profit conditional on successful entry is

$$E[\pi(\varphi, \tau)] = \int_0^\infty \int_{\varphi^*(\tau)}^\infty \pi(\varphi, \tau)\mu(\varphi, \tau)\, d\varphi d\tau.$$

The free entry condition means that dividend income Π which is aggregate profits less total paid entry costs, is zero in equilibrium. Plugging the optimal profit given by equation (3) into (7), and rearranging, yields the **free entry condition**:

$$\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w^{1-\sigma}\int\int_{\varphi^*(\tau)}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right]g(\varphi,\tau)d\varphi d\tau - wf\int\int_{\varphi^*(\tau)} g(\varphi,\tau)d\varphi d\tau = w\delta f_e. \tag{8}$$

Goods market clearing. The goods market clearing condition requires that

$$PQ = wL + T = wL + M\int_0^\infty\int_{\varphi^*(\tau)}^\infty(\tau-1)\pi(\varphi,\tau)\mu\left(\varphi,\tau\right)d\varphi d\tau. \tag{9}$$

Labor market clearing. Let M denote the measure of operating firms and M_e the mass of entrants. The total amount of labor used includes those expected to be demanded for production and those for incurring fixed costs such that

$$L = ME\left[\frac{q}{\varphi}+f\right]+M_e f_e.$$

A stationary equilibrium with a constant mass of firms in operation implies that the measure of successful entrants equals the mass of firms that exit. Thus, $\omega_e M_e = \delta M$. Another expression of the expected labor demanded by the firm, $E\left[\frac{q}{\varphi}+f\right]$, can be obtained using the optimal profit of the firm, yielding [2]

$$M = \frac{L}{\sigma\left(\frac{\delta f_e}{\omega_e}+f\right)}. \tag{10}$$

The equilibrium is determined by three variables: the zero-profit cutoff productivities (that depend on firm specific τ), the price index and aggregate quantity: $(\varphi^*(\tau), P, Q)$. Other endogenous variables (M, T) can be written as functions of these variables. The equilibrium vector is determined by three equilibrium conditions: the zero cutoff productivity (4), the free entry (8) and the goods market clearing condition (9).

[2] Plugging the firm's optimal price (2) into profit function yields the the expected optimal profit of the firm $E[\pi(\varphi,\tau)] = E\left[\frac{1}{\sigma-1}\frac{wq}{\varphi} - wf\right]$, which, combined with the free entry condition (7) gives $E\left[\frac{q}{\varphi}\right] = (\sigma-1)\left(f+\frac{\delta f_e}{\omega_e}\right)$. Plugging this equation into the labor market clearing condition yields Eq.10.

2.2 Two-Country Open-economy Model

Now we consider the two-country general equilibrium. There are two economies, Home and Foreign. Foreign firms draw their productivity from a distribution $g_f(\varphi, \tau)$, and has a labor force of L_f. In all other ways, the two countries are identical.

With trade, firms now have the option of exporting abroad. If a domestic firm exports to the Foreign economy, it solves the following problem

$$\max \ \frac{p_x q_f}{\tau} - \frac{w}{\varphi}\tau_x q_f - w f_x$$

subject to the foreign demand function

$$q = \frac{p_x^{-\sigma}}{P_f^{-\sigma}} Q_f,$$

where P_f and Q_f denote the aggregate price index and demand in Foreign. Given the same constant elasticity of demand in the domestic and export markets, equilibrium prices in the export market are a constant multiple of those in the domestic market:

$$p_x(\varphi, \tau) = \frac{\sigma}{\sigma - 1} \frac{w \tau_x \tau}{\varphi},$$

The optimal profit from servicing the foreign market,

$$\pi_x = \sigma^{-\sigma}(\sigma - 1)^{\sigma - 1} P_f^{\sigma} Q_f \tau^{-\sigma} (w\tau_x)^{1-\sigma} \varphi^{\sigma - 1} - w f_x,$$

yields an optimal cutoff for exporting:

$$\varphi_x^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{w f_x \tau_x^{\sigma-1}}{P_f^{\sigma} Q_f} \right]^{\frac{1}{\sigma-1}} w \tau^{\frac{\sigma}{\sigma-1}}. \tag{11}$$

Consumer love of variety, a fixed production cost and additional fixed cost of exporting, mean that firms would never export without also selling in the domestic market. There are, hence, two cutoff productivities relevant for the domestic economy: one for entering the domestic market as given by (4) and one for entering the foreign market, as given by (11).

To the extent that taxes τ are constant across firms, the ratio $\varphi_x^*(\tau)/\varphi^*(\tau)$ is a constant and is greater than 1 so long as $\frac{\tau_x^{\sigma-1} f_x}{f} \frac{P^\sigma Q}{P_f^\sigma Q_f} > 1$. Analogously, firms in the Foreign country are subject to two cutoff productivities, one for servicing their domestic market, and one for exporting to the Home economy

$$\varphi_f^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma-1} \left[\frac{w_f f}{P_f^\sigma Q_f} \right]^{\frac{1}{\sigma-1}} w_f \tau^{\frac{\sigma}{\sigma-1}}, \tag{12}$$

$$\varphi_{xf}^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma-1} \left[\frac{w_f f_x \tau_x^{\sigma-1}}{P^\sigma Q} \right]^{\frac{1}{\sigma-1}} w_f \tau^{\frac{\sigma}{\sigma-1}}. \tag{13}$$

where w_f denotes the foreign wages, and the fixed cost of producing and exporting are assumed to be identical in the two economies.

The free entry condition with exporting requires that

$$\int \int_{\varphi^*(\tau)} \pi(\varphi,\tau) g(\varphi,\tau) d\varphi d\tau + \int \int_{\varphi_x^*(\tau)} \pi_x(\varphi,\tau) g(\varphi,\tau) d\varphi d\tau = \delta w f_e. \tag{14}$$

The first term is the expected profits from domestic sales conditional on entry, multiplied by the probability of entry. The second term is the expect profits from export sales conditional on exporting, multiplied by the probability of exporting. The free entry condition requires that their sum be equal to the entry costs (in terms of labor).

The price index P can thus be expressed as

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left[M \int_0^\infty \int_{\varphi^*(\tau)}^\infty \left(\frac{\varphi}{w\tau}\right)^{\sigma-1} \mu(\varphi,\tau)\, d\varphi d\tau + M_f (\tau_x)^{1-\sigma} \int_{\varphi_{xf}^*(\tau)}^\infty \left(\frac{\varphi}{w_f \tau}\right)^{\sigma-1} \mu_f(\varphi,\tau)\, d\varphi d\tau \right] \tag{15}$$

Goods market clearing. The assumption of a balanced trade results in

$$M P_f^\sigma Q_f (\tau_x w)^{1-\sigma} \int_0^\infty \int_{\varphi_x^*(\tau)}^\infty \left(\frac{\varphi}{\tau}\right)^{\sigma-1} \mu(\varphi,\tau)\, d\varphi d\tau = M_f P^\sigma Q (\tau_x w_f)^{1-\sigma} \int_0^\infty \int_{\varphi_{xf}^*(\tau)}^\infty \left(\frac{\varphi}{\tau}\right)^{\sigma-1} \mu_f(\varphi,\tau)\, d\varphi d\tau \tag{16}$$

Labor market clearing. Let M denote the measure of operating firms at Home. In a stationary equilibrium in which the mass of firms are constant in both economies, the labor market condition analogous to that of the closed economy case yields

$$M = \frac{L}{\sigma\left(\delta \frac{f_e}{\omega_e} + f + \omega_x f_x\right)} \tag{17}$$

where $\omega_e = \int_0^\infty \int_{\varphi^*(\tau)}^\infty g(\varphi, \tau)\, d\varphi d\tau$ is the probability of entry, andω_x is the probability of exporting given by

$$\omega_x = \int_0^\infty \int_{\varphi_x^*(\tau)}^\infty \mu(\varphi, \tau)\, d\varphi d\tau = \frac{\int_0^\infty \int_{\varphi_x^*(\tau)}^\infty g(\varphi, \tau)\, d\varphi d\tau}{\int_0^\infty \int_{\varphi^*(\tau)}^\infty g(\varphi, \tau)\, d\varphi d\tau}.$$

A similar set of conditions holds for Foreign firms.

Normalizing the Home country wage rate to 1, there are eleven equations, the zero cutoff productivities for domestic production and exporting (4), (11), and its foreign counterparts, the free entry conditions (14) along with its foreign counterpart, the definition of the Home and Foreign price indices(15), and a goods market clearing /balanced trade equation(16), along with the measure of firms (17) and its foreign counterpart. These equations yield the equilibrium consisting of eleven unknowns $\{\varphi^*(\tau)$, $\varphi_x^*(\tau)$, $\varphi_f^*(\tau)$, $\varphi_{fx}^*(\tau)$, P, P_f, Q, Q_f, w_f, M, $M_f\}$.

Proposition 1. *The allocations, entrants, and cutoff functions* $\{Q, Q_f, M, M_f, \varphi^*(\tau), \varphi_x^*(\tau)\}$ *are independent of mean wedge* $\bar{\tau}$*. Prices* $\{P, P_f, w_f\}$ *change proportionally with* $\bar{\tau}$*, i.e.* $P(\bar{\tau}_1)/P(\bar{\tau}_2) = \bar{\tau}_1/\bar{\tau}_2$*, similarly for* P_f *and* w_f*.*

2.3 Welfare and TFP under Symmetric Equilibrium

In this subsection, we show that under distortion, there could be TFP loss after trade since trade could lead to resources flow from high productive to low productive firms when high productive firms face high distortion. Moreover, for the same reason, trade could lead to more exit of high productive firms. The loss therefore depends on how correlated the productivity with the wedges ρ and the dispersion of the wedges σ_τ. We later identify these two key parameters with the correlation of measured output wedge with value added and the dispersion of the measured wedges using the firm level data.

To illustrate how domestic distortions affect gain from trade and efficiency loss with and without trade, we consider a symmetric equilibrium with identical Home and Foreign country, i.e. both the two countries face the same domestic and trade distortions. From now on, we assume that φ and τ are jointly log-normally distributed with means $\bar{\phi}$ and $\bar{\tau}$, standard deviations σ_φ and σ_τ, and correlation ρ.

In this symmetric equilibrium, aggregate TFP is synonymous with welfare in each economy. TFP is given by

$$TFP = \frac{\sigma - 1}{\sigma}\left[M \int\int_{\varphi^*(\tau)} \left(\varphi \frac{MPL}{MPL_i}\right)^{\sigma-1} \mu(\varphi,\tau)\, d\varphi d\tau + M \int\int_{\varphi_x^*(\tau)} \left(\frac{\varphi}{\tau_x}\frac{MPL}{MPL_i}\right)^{\sigma-1} \mu(\varphi,\tau)\, d\varphi d\tau\right]^{\frac{1}{\sigma-1}} \tag{18}$$

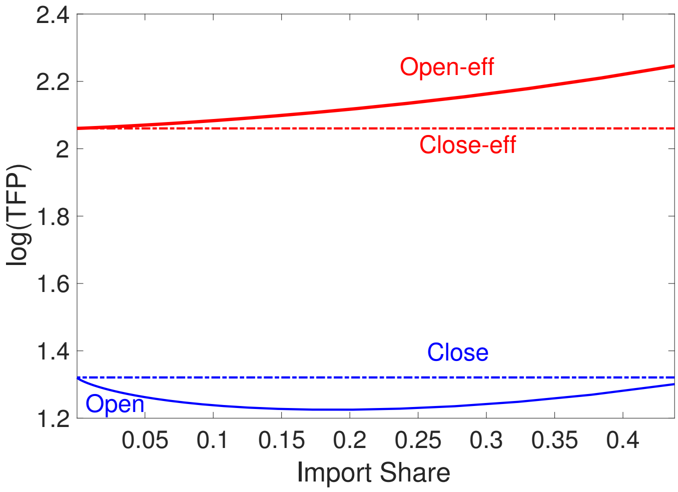
Equation (18) shows that the source of TFP loss in the presence of firm-level distortions can arise from a misallocation of resources, captured by dispersions in MPL/MPL_i, and a misallocation caused by selection and entry mechanisms as captured by the case where M, φ^*, φ_x^* are different from their respective efficient levels.

In the absence of closed-form expressions, a numerical example can illustrate the two types of misallocation. Figure 1.1 plots the level of TFP against import share in various scenarios: the efficient case without distortions, the case with distortions, and when the economy is closed or open. Three observations immediately follow: 1) there is a TFP loss in the case with distortions compared to the case without; 2) opening up to trade leads to productivity gains in the efficient case; 3) however opening up generates a productivity loss with distortions. In order to understand the mechanisms behind these results, we first analyze the closed-economy case before analyzing the impact of trade openness.

TFP loss in a Closed Economy. The analysis for the close economy case is most closely related to that in HK, except that there is a selection mechanism induced by entry/exit at play. That there are productivity losses in the inefficient economy when distortions are not identical across firms may be obvious. However, there are two sources of losses: one induced by a misallocation of resources among an observed, fixed set of operating firms, and one arising from an 'unobserved' misallocation of resources among operating and non-operating firms–that is, between potential entrants, operating firms, and displaced firms.

To see this, we can decompose the deviation of TFP from its efficient level into an ex-

Figure 1.1: TFP Loss from Trade



plicit misallocation effect—as emphasized by HK, and an implicit misallocation effect—generated by entry and selection:

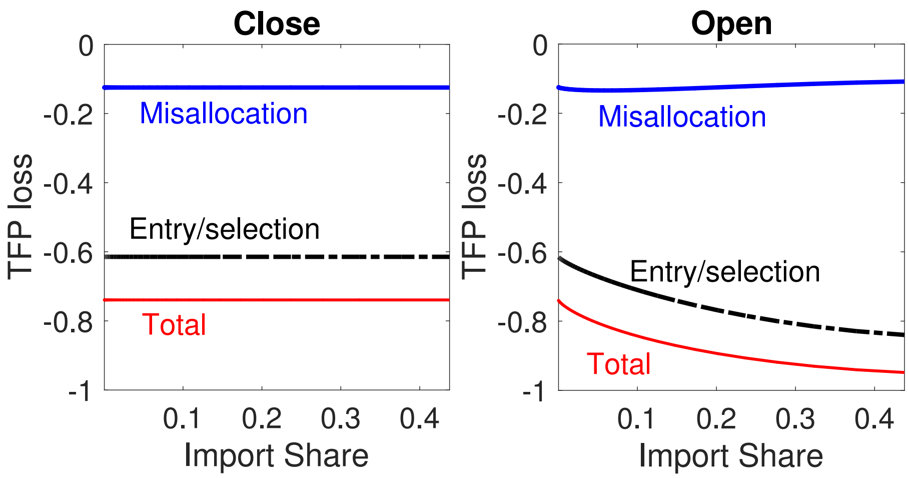
$$\log TFP - \log TFP_{eff} = \underbrace{\log TFP - \log TFP_{HK}}_{\text{misallocation loss}} + \underbrace{\log TFP_{HK} - \log TFP_{eff}}_{\text{entry and selection loss}},$$

where TFP_{eff} pertains to the case without wedges: the marginal product of labor is the same across all firms and equal to the aggregate MPL, and entry is endogenously determined in this case. The HK measure of TFP corresponds to the level in the case without distortions but M, φ^*, and φ_x^* are fixed at the level with distortions:

$$\begin{aligned} TFP_{eff} &= \frac{\sigma-1}{\sigma}\left[M^{eff}\int_{\varphi^{eff*}}^{\infty}\varphi^{\sigma-1}\mu^{eff}(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}}, \\ TFP_{HK} &= \frac{\sigma-1}{\sigma}\left[M\int_{\varphi^*}^{\infty}\varphi^{\sigma-1}\mu(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}}. \end{aligned}$$

Figure 1.2 plots, for the same numerical example, the decomposition of these effects in a closed economy (left panel). While the misallocation among a fixed measure of operating firms (HK effect) induce a sizeable TFP loss, the loss arising from the implicit misallocation among operating and non-operating firms is also significant. Allowing for entry/selection effects thus captures the full scale of misallocation arising from distortions.

Figure 1.2: TFP loss Decomposition



TFP Loss in an Open Economy. The right panel in Figure 1.2 shows deviations of TFP in an open economy, where the corresponding efficient TFP and TFP_{HK} are analogous to the closed-economy case:

$$
\begin{aligned}
TFP_{eff} &= \frac{\sigma-1}{\sigma}\left[M^{eff}\int_{\varphi^{eff*}}^{\infty}\varphi^{\sigma-1}\mu^{eff}(\varphi)\,d\varphi + M^{eff}\int_{\varphi_x^{eff*}}^{\infty}(\frac{\varphi}{\tau_x})^{\sigma-1}\mu^{eff}(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}} \\
TFP_{HK} &= \frac{\sigma-1}{\sigma}\left[M\int_{\varphi^{*}}^{\infty}\varphi^{\sigma-1}\mu(\varphi)\,d\varphi + M\int_{\varphi_x^{*}}^{\infty}(\frac{\varphi}{\tau_x})^{\sigma-1}\mu(\varphi)\,d\varphi\right]^{\frac{1}{\sigma-1}}.
\end{aligned}
$$

The numerical results show that while openness does not significantly alter measured misallocation, it largely worsens the misallocation of operating and non-operating firms. What this shows is that TFP losses in an open economy are largely driven by the distortions' effect on selection/exit mechanisms.

TFP Loss due to Trade. Now to understand why opening up can lead to a TFP or welfare loss, we rewrite TFP in equation (18) into two components: varieties and average productivity, i.e.

$$
TFP = \frac{\sigma-1}{\sigma}\underbrace{(M+M_x)^{\frac{1}{\sigma-1}}}_{\text{varieties}}\underbrace{\left[\frac{M\tilde{\varphi}^{\sigma-1}+M_x(\tau_x^{-1}\tilde{\varphi}_x)^{\sigma-1}}{M+M_x}\right]^{\frac{1}{\sigma-1}}}_{\text{average productivity}}
$$

where $\tilde{\varphi}_t$ is given by

$$\tilde{\varphi}_t = \left[\frac{M}{M+M_x} \int \int_{\varphi^*(\tau)}^{\infty} (\varphi \frac{MPL}{MPL_i})^{\sigma-1} \mu\left(\varphi,\tau\right) d\varphi d\tau + \frac{M_x}{M+M_x} \int \int_{\varphi_x^*(\tau)}^{\infty} (\frac{\varphi}{\tau_x} \frac{MPL}{MPL_i})^{\sigma-1} \mu_x\left(\varphi,\tau\right) d\varphi d\tau \right]^{\frac{1}{\sigma-1}}.$$

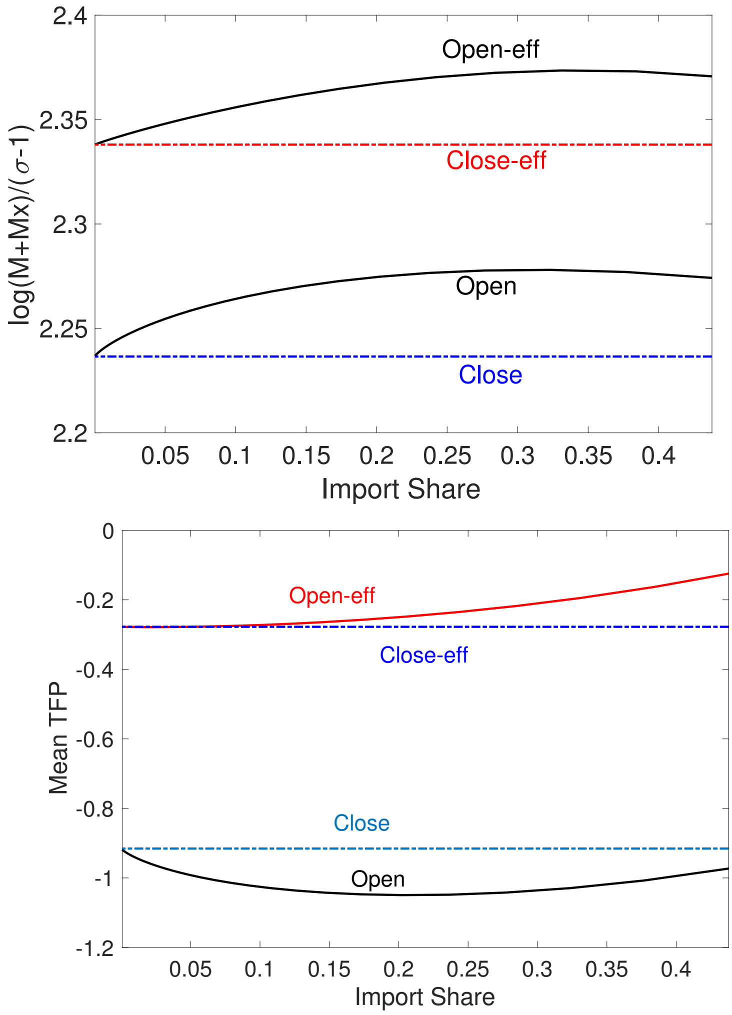
The average productivity is a weighted average of the φ's (harmonic mean weighted by output share), and is a direct analogue to the average productivity definition in Melitz.[3] Difference, however, is that the weights in this average productivity reflect not only the firms' output shares, but also their output wedges (note that $MPL_i = \tau_i$ when $w \equiv 1$). In the Melitz model, both varieties and average productivity typically rise, leading to an unambiguous TFP gain. In the current model with distortions, varieties are likely to increase but average productivity can fall, as shown in Figure 1.3.

Why does the "average productivity" of firms fall when the economy opens up to trade? The basic intuition is that trade can induce resources to flow from high to low productivity firms (rather than the other way around as in Melitz). Moreover, the previous analysis suggests that a sizeable portion of this reshuffling of resources occur among operating and non-operating firms, rather than among existing firms. Trade allows the highly subsidized firms to become larger, potentially forcing out some productive firms from the market and preventing high-productivity potential entrants from entering the market.

Exactly how trade can reduce efficiency is made more transparent by taking a closer look at the selection/entry mechanisms. Figure 1.4 illustrates this mechanism using the same numerical example as before. The density of firms is shown by a heat map of firms that lie along a positively sloped tax-productivity line under a case with correlation of φ and τ of $\rho = 0.8$. What this figure shows in the first instance is that the productivity cutoff for production and exports is no longer determined solely by productivity, but also by domestic distortion. Only firms below the cutoff line can operate. It also shows that with the assumed positive correlation between taxes and productivity, a large mass of highly-productive firms are excluded from servicing the market altogether. Second, as the economy opens up, the cutoff line shifts downward. Even if firms have the same level of

[3] The interpretation of this variable is that an industry comprised of M firms with any distribution of productivity levels that yields the same productivity level $\tilde{\varphi}_t$ will also induce the same aggregate outcome as an industry with M representative firms sharing the same productivity level $\varphi = \tilde{\varphi}_t$.

Figure 1.3: Varieties and Average Productivity



productivity, some with higher taxes may be displaced while those with lower ones will survive. This downward shift of the cutoffs allows for some low productivity and high subsidy firms to survive and gain market share.

Figure 1.4: Selection Effects

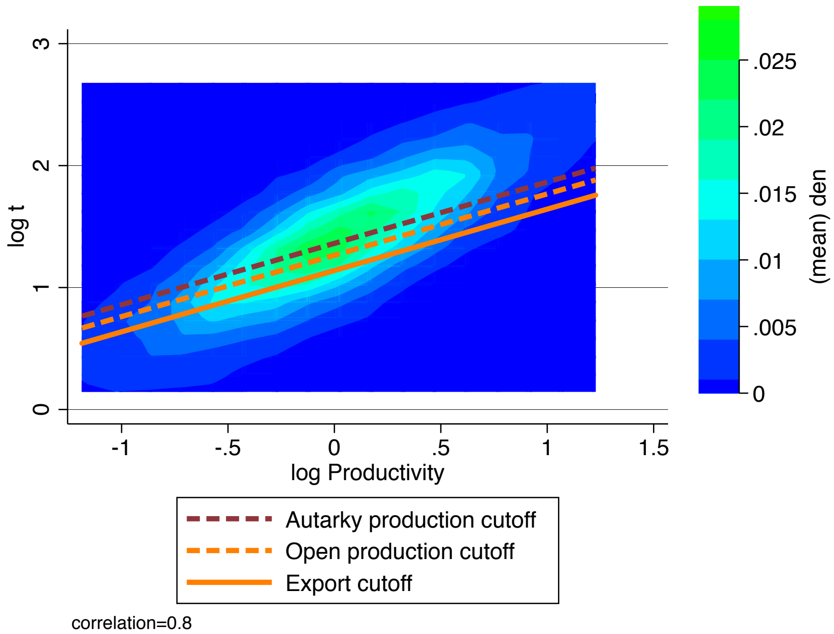
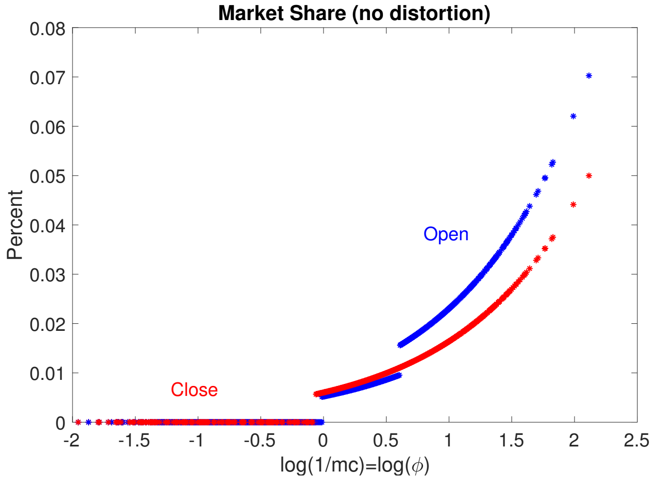


Figure 1.4 illustrates how the cutoff line shifts, but in order to see more clearly how trade liberalization can incur selection-induced losses, consider Figure 1.5 and 1.6. These figures plot the market share of firms in the closed and open economies. Figure 1.5 shows the case without distortions. Firms with the same productivity level have the same marginal cost; their market share, above a cutoff productivity, rises with their productivity. Comparing the blue and red lines show that above the export cutoff, more productive firms have higher market shares in the open economy than in the closed economy, demonstrating that these firms expand under trade liberalization. This happens at the cost of displacing other less productive firms' market share, or driving them out of the market entirely. Here, the example clearly demonstrates that resources move from less productive to more productive firms as an economy opens up to trade.

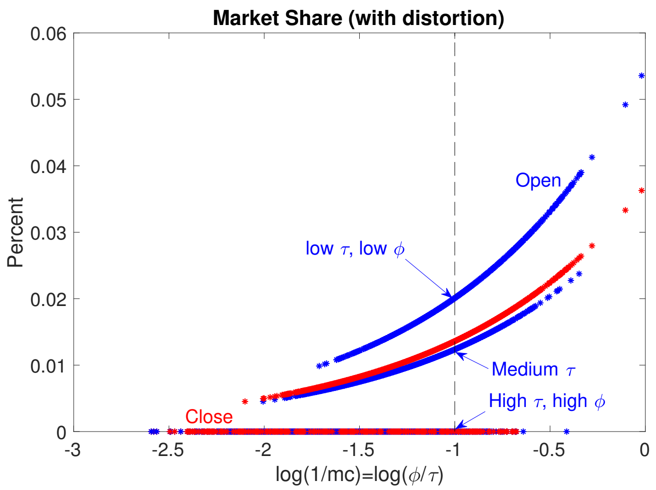
Figure 1.6 shows the firm's market share in the case with distortions. Firms may share the same marginal cost and face the same potential revenues from sales even with different levels of productivity. However, their after-tax profits may differ, and thus their market

Figure 1.5: Gains from Trade without Distortions



share can also differ. Consider the point at which the (log) effective productivity level (φ/τ) is at -1. At this point, a firm with high, medium and low level of productivity face the same marginal costs. However, the high productivity firm is also subject to high taxes and thus low after-tax profit, and does not make the cut for production. The medium tax- medium productivity firm has positive market share but loses out to the low tax -low productivity firm when the economy opens up. Resources are reallocated from the more productive to the less productive firms. Also, there is no longer a neat line up of market shares according to productivity: there a wide range of productivities for which production is excluded.

Figure 1.6: Losses from Trade with Distortions



Comparison with ACR. Arkolakis, Costinot, and Rodríguez-Clare (2012) show that the changes in welfare associated with globalization, modeled as a change in iceberg trade costs, can be inferred using two variables across a wide class of trade models: (i) changes in the share of expenditure on domestic goods; and (ii) the elasticity of bilateral imports with respect to variable trade costs (the trade elasticity). Different trade models can have different micro-level predictions, sources of welfare gains, and different structural interpretations of the trade elasticity. But conditional on observed trade flows and an estimated trade elasticity, the welfare predictions are the same. Of course, the generality of this formulation relies on a certain set of macro-level restrictions. We next compare the welfare decomposition arising from the current framework with the ACR formulation. Differentiating Eq.15, we obtain

$$dlnP = -\frac{1}{\gamma_d(\varphi^*) + \sigma - 1}\left[dlnM_e - dln\lambda + \frac{\gamma_d(\varphi^*)}{\sigma - 1}dln(wL+T)\right]$$

where

$$\gamma_d(\varphi^*) = \frac{\int_0^\infty (\frac{\varphi^*}{\tau})^{\sigma-1} g(\varphi^*, \tau)\varphi^* d\tau}{\int_0^\infty \int_{\varphi^*}^\infty (\frac{\varphi}{\tau})^{\sigma-1} g(\varphi, \tau) d\varphi d\tau}$$

can be interpreted as the hazard rate for the distribution of log firm sales. Note that different from ACR where γ is a parameter, here $\gamma(\varphi^*)$ is endogenous and differs across markets and levels of trade costs. The cutoff productivity satisfies

$$\varphi^* \propto P^{-1}(PQ)^{-\frac{1}{\sigma-1}}\tau^{\frac{\sigma}{\sigma-1}}.$$

This cutoff is inversely related to the price index P and aggregate spending PQ, and positively related to distortions τ. A higher price index means lower competition in the market, thus lowering the hurdle of survival rate and thus the cutoff productivity. Higher aggregate demand and lower taxes also lower this hurdle.

To directly compare with the ACR formula, one can write the change in welfare as

$$dlnW = \frac{1}{\gamma_d(\varphi^*) + \sigma - 1}\left[\underbrace{-dln\lambda}_{\text{ACR}} + \underbrace{dlnM_e}_{\text{entry}} + \underbrace{\frac{\gamma_d(\varphi^*)}{\sigma - 1}dln(wL+T)}_{\text{selection from AD}}\right] + \underbrace{dln(wL+T)}_{\text{change in expenditure}} \quad (19)$$

where λ denotes the domestic share. The first term is the conventional sufficient statistics for the gain from trade; however, trade flows are of course affected by distortions and the elasticity. The second term is the positive effect of entry. In the special case where productivity is drawn from a Pareto distribution, and there are no firm-specific distortions, this term is zero (given that L is fixed and w is normalized to 1). That is, the measure of entrants is constant. Under a more general distribution, however, aggregate profits are no longer constant shares of aggregate revenue. Even without distortion, the measure of entrants varies with trade cost and affects the gain from trade, as shown in Melitz and Redding (2015). In fact, in the presence of distortions, aggregate profits change with the distribution of distortions as well as with firm selection. Thus, M_e changes with trade costs in our model. The third and the last term capture the effects of change in aggregate demand PQ or $WL+T$ on welfare variation. There are two effects, the selection effect and the change in expenditures.

The formula is useful in directly comparing with the ACR formula, even though it is not fully transparent on how distortions affect welfare since all terms are affected including the hazard rate γ. Our formula shows that above and beyond the observed trade flow, there are other sources of gains and losses including entry and selection. Most importantly, trade changes the allocation or misallocation of the resources, which in turn affects the aggregate expenditure and thus welfare in the economy. In particular, the last three terms tend to be negative with distortions, bring the gains from trade smaller or even to a loss.

We can use more equilibrium conditions and replace $\ln(WL+T)$ in equation (19) with $\ln\lambda$ and $\ln M_e$, which gives the following Proposition 2.

Proposition 2. *With firm level distortions, the change of welfare associated with an iceberg cost shock is*

$$dlnW = \frac{1}{\gamma_1(\varphi^*,\varphi_x^*)+\sigma-1}\left[\beta_1(\varphi^*,\varphi_x^*)dln\lambda+\beta_2(\varphi^*,\varphi_x^*)dlnM_e\right],$$

where

$$\gamma_1(\varphi^*,\varphi_x^*) = (1-S_{\tau x})\gamma_{\tau d}+S_{\tau x}\gamma_{\tau x}+S_{\tau x}\frac{\gamma_{\tau x}+\sigma-1}{\gamma_x+\sigma-1}(\gamma_d-\gamma_x),$$

$$\beta_1(\varphi^*,\varphi_x^*) = \frac{S_{\tau x}}{1-\lambda}\frac{\gamma_{\tau x}+\sigma-1}{\gamma_x+\sigma-1}\left(\frac{\sigma\gamma_d}{\sigma-1}+\sigma-1\right)-\frac{\sigma\gamma_1}{\sigma-1}-\sigma.$$

$$\beta_2(\varphi^*, \varphi_x^*) = \frac{\sigma}{\sigma - 1}(\gamma_1 - \gamma_d) + 1.$$

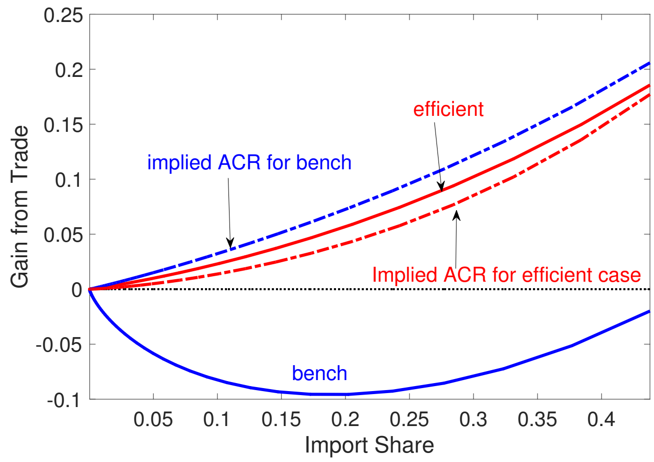
γ_d and γ_x represent the hazard function for the distribution of log firm sales within a market. $\gamma_{\tau d}$ and $\gamma_{\tau x}$ represent the hazard function for the distribution of log after tax sales within a market. $S_{\tau x}$ is the share of after tax revenue from the foreign market.[4]

1. *Without distortions and with a general productivity distribution, $\gamma_{\tau d} = \gamma_d$ and $\gamma_{\tau x} = \gamma_x$, $S_{\tau x} = 1 - \lambda$, hence $\gamma_1(\varphi^*, \varphi_x^*) = \gamma_d(\varphi^*)$, $\beta_1 = -1$ and $\beta_2 = 1$. $dlnW = \frac{1}{\gamma_d(\varphi^*)+\sigma-1}\left[-dln\lambda + dlnM_e\right]$. Micro structure matters for $\gamma_d(\varphi^*)$ and welfare as in Melitz and Redding (2015).*

2. *Without distortions, and productivity follows a Pareto distribution, $\gamma_d(\varphi^*)$ is a constant parameter, and $dlnM_e = 0$, hence $dlnW = \frac{1}{\gamma_d+\sigma-1}\left[-dln\lambda\right]$ as in Arkolakis et al (2012).*

3. *With distortions, additional micro structure, i.e. joint distribution of distortion and productivity also matters for welfare.*

Figure 1.7: Gains from Trade



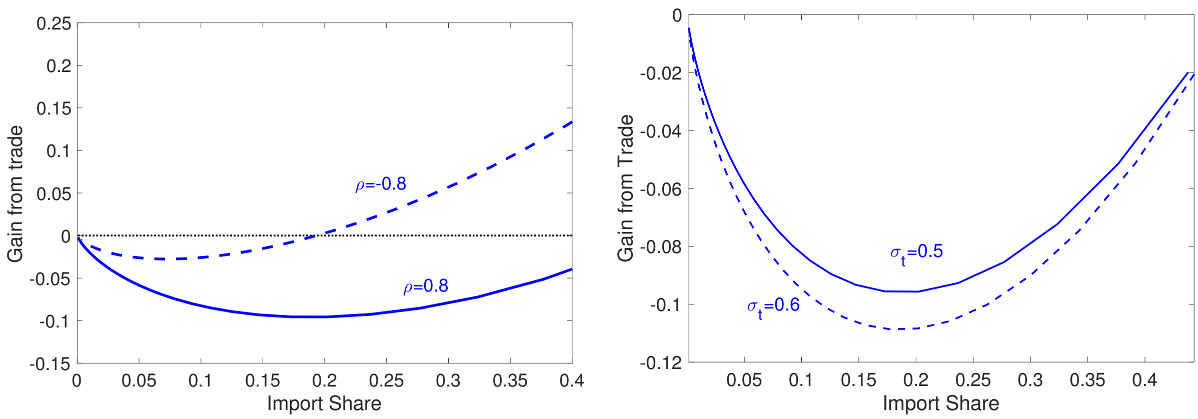
With distortions, additional micro structure, i.e. joint distribution of distortion and productivity, also matters for welfare. In addition, $d\ln W$ can be negative and a country could lose from trade. As Arkolakis, Costinot, and Rodríguez-Clare (2012) and Melitz and Redding (2015) point out, only the partial trade elasticity is observed empirically as it is estimated from a gravity equation with exporter and importer fixed effects. This partial trade elasticity corresponds to $\gamma_x + \sigma - 1$. The Figure 1.7 (taking the same parameters as before) shows the welfare gains under the efficient case, the benchmark case with distortions, and the welfare gains using the ACR formula in both cases. The figure shows that using

[4]See Appendix for definitions on $S_{\tau x}$, $\gamma_{\tau x}$, $\gamma_{\tau d}$, γ_x, and γ_d.

the ACR formula to infer welfare gains when there are firm-level distortions predict trade gains, rather than losses. The two cases without distortions (1 and 2 in Proposition 2) predict welfare gains that are fairly close—as the difference mainly lies in assumptions about the distribution of productivity. Our benchmark prediction differs markedly from the other three cases in that it predicts welfare losses rather than gains. The results also demonstrate that using aggregate observables to infer welfare gains as in ACR can be very misleading in evaluating the impact of trade when distortions are present.

Distribution of Distortions. The distribution of distortions is an important determinant to the gains to trade and TFP changes. There are two key parameters: ρ, the correlation of τ and φ, and σ_τ, the dispersion of τ. The correlation of distortion and productivity is important insofar as a higher correlation means that more productive firms are more likely to be excluded from the market. But reductions in welfare is possible even when the correlation is negative. The reason is that there are always some productive firms that will be excluded, leading to a possible welfare loss. Figure 1.8(a) illustrates this. It compares the gain from trade for $\rho = 0.8$, under our benchmark numerical example, and for $\rho = -0.8$, where productivity and distortion are highly negatively correlated and other parameters are the same as in the benchmark example. Under $\rho = -0.8$, the welfare gain (loss) from trade is always larger (smaller) than that in the case of $\rho = 0.8$. But when the import share is below 20%, there are still losses from trade.

Figure 1.8: Gains/Loss from Trade



(a) Correlation Matters

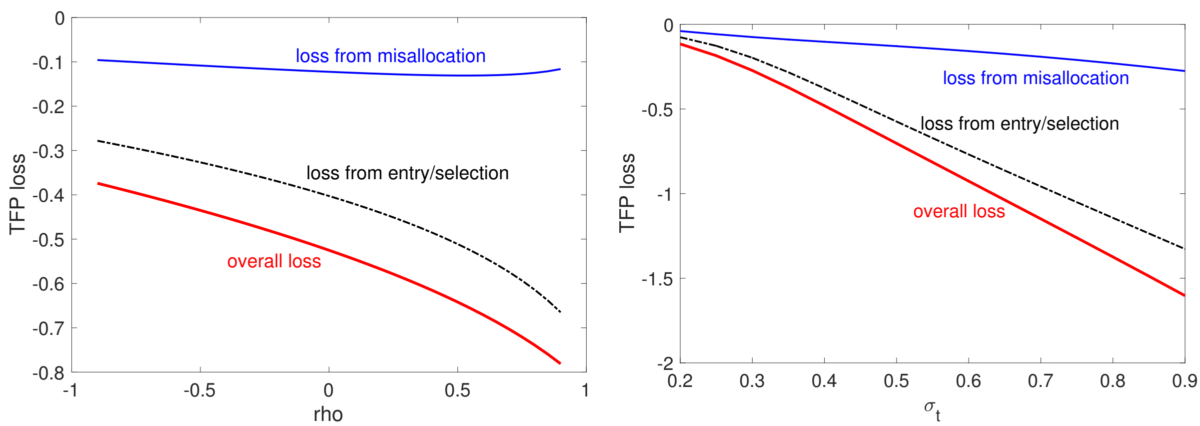
(b) Dispersion Matters

Figure 1.8 (b) compares the gain from trade under different σ_τ and other parameters are the same as in the benchmark example. The welfare gain (loss) from trade is always larger (smaller) when σ_τ is smaller.

Figure 1.9 (a) exhibits how TFP loss varies with ρ under an open economy with a fixed level of trade cost f_x and τ_x. The red line plots the total TFP loss— the difference between the levels of TFP in the case with distortions and without distortions.The blue line plots the TFP loss compared with HK efficiency, and the dashed black line is the TFP loss due to entry and selection margin, as a function of ρ. First, a higher ρ is associated with a higher total efficiency loss. Second, the TFP losses induced by misallocation and entry and selection are both important; however, the TFP losses from entry and selections margin becomes more prominent as ρ increases.

Note that different from the standard HK analysis, the correlation between productivity and wedge affects TFP losses dramatically. The standard HK analysis has no entry margin and uses a joint log-normal distribution between productivity and wedge. In that analysis, TFP loss is fully captured by the dispersion of wedge, and the correlation of productivity and wedge does not matter at all. Our analysis is more general, featured with entry and exit into domestic and foreign market. The correlation between τ and φ is important as shown in Figure 1.9 (a).

Figure 1.9: TFP Loss Decomposition



(a) across ρ (b) across σ_τ

Figure 1.9 (b) exhibits how TFP loss varies with the standard deviation of τ. Again, we show three lines: the overall TFP loss, loss from misallocation, and loss from entry and selection. Higher dispersion of distortion leads to more misallocation and in turn higher loss in entry and selection. The overall losses increases with the dispersion of τ.

In summary, the size of TFP loss and welfare after opening up depends on the correlation of φ and τ and the dispersion of τ, σ_τ. The firm level data helps us identify these parameters. Specifically, in the next section, we will measure the firm-level output wedge and use its dispersion and its correlation with firm value added to identify ρ and σ_τ.

3 Empirical Results

Data. Our data for Chinese firms are from an annual survey of manufacturing enterprises collected by the Chinese National Bureau of Statistics. The dataset includes non-state firms with sales over 5 million RMB (about 600,000 US dollars) and all of the state firms for the 1998-2007 period. We have information from the balance sheet, profit and loss statements, and cash flow statements, which incorporate more than 100 financial variables. The raw data consist of over 125,858 firms in 1998 and 306,298 firms by 2007.

Backing out Key Parameters. To back out factor and output distortions we now adopt Cobb-Douglas production function for a firm i in industry j, $y_{ji} = \varphi_{ji} k_{ji}^{\alpha} \ell_{ji}^{1-\alpha}$. The marginal revenue product of labor and capital is $\partial(p_{ji}y_{ji})/\partial(\ell_{ji})$ and $\partial(p_{ji}y_{ji})/\partial(k_{ji})$, and with firm profit maximization, yields

$$MRPL_{ji} \equiv \frac{\sigma-1}{\sigma}(1-\alpha_j)\frac{p_{ji}y_{ji}}{\ell_{ji}} = \tau_{ji}^{\ell} w_j$$

$$MRPK_{ji} \equiv \frac{\sigma-1}{\sigma}\alpha_j \frac{p_{ji}y_{ji}}{k_{ji}} = \tau_{ji}^{k} r_j,$$

where w_j and r_j denote industry-level wages and interest rates. These marginal products are proportional to the average products, assuming common markups and capital elasticities, and no fixed cost as in HK. Firms equalize the after-tax marginal revenue products of factors. In the absence of distortions, revenue per person should be equalized across firms. In the presence of distortions, a firm that faces higher taxes will end up with a higher marginal revenue product and less capital/labor than an otherwise identical firm facing a subsidy.

Equilibrium allocations yield

$$p_{ji}y_{ji} \propto \left[\frac{\varphi_{ji}}{(\tau^k_{ji})^{\alpha_j}(\tau^\ell_{ji})^{1-\alpha_j}}\right]^{\sigma-1},$$

from which firm-level productivity can be inferred as

$$\varphi_{ji} = (P_j^{\sigma-1}X_j)^{\frac{1}{1-\sigma}} \frac{(p_{ji}y_{ji})^{\frac{\sigma}{\sigma-1}}}{k_{ji}^{\alpha_j}\ell_{ji}^{1-\alpha_j}}. \tag{20}$$

What matters is the relative marginal revenue and relative productivities–their deviations from the industry mean. Specifically, the measured relative $MRPK_{ji}$ or the relative average product ($ARPK_{ji}$) is calculated as $\log\left(p_{ji}y_{ij}/k_{ij}\right) - \log\left(\overline{p_j y_j/k_j}\right)$ where $\overline{p_j y_j/k_j}$ is the industry mean of average product. The same holds for the measured marginal revenue of labor. The elasticity of output with respect to capital in each industry is taken to be 1 minus the labor share in the corresponding industry in the U.S, following HK. The reason that labor shares are not computed from Chinese data is that the prevalence of distortions would affect these elasticities, and industry-level elasticities and distortions cannot be separately identified. The U.S. is taken to be the benchmark as the relatively undistorted economy. These labor share comes from the U.S. NBER productivity database, which is based on the Census and ASM. We take the benchmark elasticity of substitution parameter σ to be 3, but experiment with other values within the conventional range. Different from HK, we take a firm's employment to measure ℓ_{ji} rather than the firm's wage bill. This addresses the problem that Chinese wage data implies too low of a labor share as measured by input-output tables and the national accounts. We define the capital stock as the book value of fixed capital net of depreciation.

Measured Distortions. We find large dispersions in measured distortions in China, similar to the levels in HK for the year 1998 and 2005. Measured distortions have come down over time, between 1998 and 2007, as evident in Table 1. There is also greater dispersion in the average product of capital than there is in the average product of labor.

We next turn to investigating further what factors are systematically related to measured distortions. Table 2 reports the regression results of the relative average product of capital of a firm (measured as value-added divided by total capital, deviated from industry mean) on a set of variables. The coefficient on firm-productivity is large and significant; 1 percent increase in relative productivity is associated with a 0.7 percent increase in relative distortion. Moreover, more than half the variation in distortions is explained by productivity alone. Also consistent with intuition, a state-owned enterprise is likely to have lower taxes, as are foreign-owned firms or exporting firms. The result on exporters is consistent with model implications: given productivity, exporters must have lower taxes. Similar results hold for the average product of labor regression results, in Table 3.

Table 1: Dispersion of Distortions

	1998	2001	2004	2007
std(APK(deviation from industry mean))	1.348	1.306	1.241	1.185
std(APL(deviation from industry mean))	1.184	1.039	0.940	0.923

Relationship between productivity and distortion. As shown above, the correlation between the measured factor distortions and measured productivity is high. Figure 1.10 displays the relationship between the measured φ and APK; a similar relationship holds for φ and APL. It is not a priori clear why more productive firms are necessarily more distorted. Though this relationship was not important in the special case illustrated by HK–the assumption of a joint log normal distribution between the two variables—it does matter for more general cases, and it is certainly quantitatively important in the exercise we undertake.

This is not the first time that this relationship is uncovered. China is also not the only country for this positive relationship exists. In fact, many countries display a similar positive relationship, the degree of which differs across countries. But how does one make sense of this? It turns out that selection mechanisms alone can generate this positive relationship. In previous sections we have shown that even if the underlying correlation between productivity and factor distortions is negative, the observed correlation can become positive with selection, with the simple reason being that higher taxed firms must be

Table 2: APK Regressions

VARIABLES	(1) $\ln(APK)$	(2) $\ln(APK)$	(3) $\ln(APK)$	(4) $\ln(APK)$	(5) $\ln(APK)$	(6) $\ln(APK)$
$\ln(TFPQ)$	0.652***	0.697***	0.706***	0.705***	0.707***	0.711***
	(147.7)	(153.0)	(154.8)	(153.9)	(160.3)	(168.1)
age				-0.00178***	-0.00191***	-0.00174***
				(-8.772)	(-9.477)	(-9.386)
1.soe					-0.116***	-0.109***
					(-3.388)	(-3.313)
1.foreignown					-0.460***	-0.379***
					(-19.74)	(-20.60)
exporters						-0.233***
						(-13.82)
Constant	-3.617***	-3.280***	-3.204***	-3.173***	-3.049***	-3.042***
	(-134.6)	(-60.38)	(-54.16)	(-53.37)	(-44.45)	(-44.88)
Observations	1,616,507	1,616,507	1,506,572	1,505,657	1,505,657	1,505,657
R-squared	0.566	0.628	0.640	0.640	0.655	0.659
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	Yes	Yes	Yes	Yes
Location FE	No	No	Yes	Yes	Yes	Yes

Robust t-statistics clustered at the four-digit industry level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 1.10: Correlation Between Measured MPK and Measured TFPQ

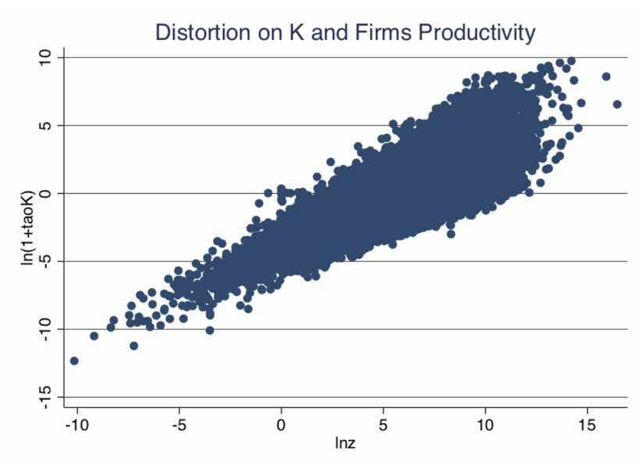


Table 3: APL Regressions

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	ln(APL)	ln(APL)	ln(APL)	ln(APL)	ln(APL)	ln(APL)
ln($TFPQ$)	0.530***	0.570***	0.569***	0.568***	0.565***	0.567***
	(110.7)	(228.5)	(222.5)	(224.2)	(228.4)	(229.4)
age				-0.00161***	-0.00140***	-0.00128***
				(-9.072)	(-8.783)	(-8.440)
1.soe					-0.0840***	-0.0787***
					(-7.136)	(-7.057)
1.foreignown					0.0615***	0.123***
					(3.925)	(8.317)
exporters						-0.175***
						(-27.08)
Constant	-3.593***	-3.274***	-3.229***	-3.201***	-3.172***	-3.167***
	(-123.2)	(-109.1)	(-103.2)	(-100.5)	(-95.80)	(-97.30)
Observations	1,616,507	1,616,507	1,506,572	1,505,657	1,505,657	1,505,657
R-squared	0.619	0.691	0.699	0.700	0.701	0.705
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	Yes	Yes	Yes	Yes
Location FE	No	No	Yes	Yes	Yes	Yes

Robust t-statistics clustered at the four-digit industry level in parentheses

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

more productive in order to stay in the market. At the very least, the selection mechanism will strengthen any underlying correlation that the two variables have. What is interesting about the relationship in the data is a line that seems to cut from above is not dissimilar to the cutoff line in the model.

Another reason behind this positive relationship is that we are measuring average products instead of marginal products because of fixed costs. Measured marginal products using APL are affected by fixed costs, as $APL = p_{ji}y_{ji}/(\ell_{ji} + f_{ji})$, as is measured productivity, $\varphi = y_{ji}/(\ell_{ji} + f_{ji})$. The presence of fixed cost will tend to induce a positive relationship between the two.

An important point is that one cannot use the observed correlation as the underlying correlation between the two variables (ρ). But to compute the impact of distortions on welfare and productivity gains, one would need to know the underlying correlation ρ, and thus one needs micro data and a structural model to uncover the true correlation.

4 Quantitative Results

This section estimates the quantitative effects of trade when accounting for domestic distortions. The two countries Home and Foreign, are calibrated to data from correspond to the China and the U.S.

Table 4 reports the parameters chosen based on standard moments and calibrated. We normalize Home labor L to 1 and Foreign labor L_f to 0.2 to match the relative labor force of US to China. Productivity levels are set to match the relative GDP of US to China. Given that Foreign affects Home only though aggregate variables, we can assume that Foreign is absent distortions, while taking $f_e, f, f_x, \tau_x, \sigma_\phi$ to be the same as those in Home. We set the elasticity of substitution between varieties σ to be the one HK adopted, 3, which is consistent with the estimates using plant-level US manufacturing data in Bernard et al. (2003).

The remaining 8 parameters are estimated jointly, to match the moments from the model with their data counterparts. Table 4 and 5 reports the estimated parameters and the moments in the data and model. The moments we choose are most relevant and sensi-

Table 4: Model Parameters

Parameter	*Value*	*Identification*
Elasticity of substitution σ	3	
Home labor L	1	normalization
Foreign Labor L^f	0.2	Relative labor size of US to China
	Internal Estimation	
Entry cost f_e	0.2	Fraction of firms producing
		(one year survive rate in the data)
Fixed cost of producing f	0.015	mean-lowest 5% $ln(K^\alpha L^{1-\alpha})$
Fixed cost of export f_x	0.12	fraction of firm exporting
Iceberg trade cost mean τ_x	1.5	export intensity
Std. productivity σ_φ	1.2	std of existing firms lnVA
Std. wedge σ_τ	0.9	std of existing firms $ln(K^\alpha L^{1-\alpha})$
Corr(wedge, productivity) ρ	0.86	Corr(lnVA, $ln(VA/K^\alpha L^{1-\alpha})$)
Mean foreign prod $\mu_{f\varphi}$	5.5	Relative GDP of US to China

Table 5: Data and Model Moments

Target Moments	Data(2005)	Model
Fraction of firms producing ω_e	0.85	0.85
Mean $-$ lowest 5% for $ln(K^\alpha L^{1-\alpha})$	1.82	1.53
Fraction of firm exporting	0.30	0.28
Export intensity	0.41	0.42
std of existing firms ln(VA)	1.20	1.26
std of existing firms $ln(VA/K^\alpha L^{1-\alpha})$	0.93	0.84
Corr(lnVA, $ln(VA/K^\alpha L^{1-\alpha})$)	0.41	0.35
Relative real GDP of US to China	1.79	1.73

tive to variations in the model parameters. Clearly, every parameter affects the GE and other moments. However, the parameter that are most relevant to matching the fraction of surviving firms is the entry cost f_e, as $\omega_e E[\pi(\phi,\tau)] = wf_e$. Lower entry costs induces more entrants to pay the costs, and thus a lower fraction of survivors. To identify the fixed cost f, we know that the smallest firms have their profit just cover fixed cost, so that after- tax profit $\pi = wf$ and $wl_{min} = (\sigma-1)wf$ and the mean of firms labor $wl_{mean} = (\sigma-1)(E[\pi(\phi,\tau)] + wf) = (\sigma-1)(\frac{wf_e}{\omega_e} + wf)$, hence mean-lowest 5% $ln(K^\alpha L^{1-\alpha}) = \frac{\frac{f_e}{\omega_e}+f}{f}$ helps us to identify f.

We calibrate τ_x to match the fraction of exports in exporters sales in Chinese manufacturing. The resulting parameter $\tau_x = 1.5$ is inline with the estimate of 1.7 in Anderson and Van Wincoop (2004), and the 1.83 in Melitz and Redding (2015). The dispersions in productivity and wedges, and correlation between them are important for matching the observed joint distribution between value-added and inputs in the data. Table 5 shows that the discrepancy between our model and data moments is reasonably small, though we underestimate the dispersion in distortions and slightly overestimate the dispersion in size. An important variable is the correlation between size and distortions, Corr(lnVA, $ln(VA/K^\alpha L^{1-\alpha})$. This variable is more positive the higher is $\rho\frac{\sigma_\varphi}{\sigma_\tau}$, where ρ is the underlying correlation between wedges and productivity. A higher underlying correlation and a lower dispersion in wedges raise the observed correlation between value added and inputs.

4.1 Implied Gain from Trade and TFP loss

Table 6 reports the gain from trade and efficiency losses for both Home and Foreign. The upper panel of the table compares welfare and TFP in the open economy to those in the closed economy. In the benchmark estimation, the gain from trade for Home is 4.4%. Without distortions, the gains from trade is more than doubled (9.8%). Foreign's gain from trade is about 8.2% when Home has domestic distortions. Getting rid of Home distortions makes the foreign country benefit more from trading with Home—a 19% of welfare gain.

Note that the standard trade models, as in ACR, compute the welfare gain using aggregate import shares and abstracts from micro-level distributions. To see whether the

Table 6: Welfare and TFP

	Open relative to close			
	Welfare	TFP	Import Share	ACR gain
Home (%)				
Benchmark	4.4	-2.9	30.8	12.7
No-distortion	9.8	13.3	20.8	10.1
Foreign(%)				
Benchmark	8.2	12.9	17.9	6.9
No-distortion	18.9	13.3	35	17.6
	TFP loss: Distortion relative to no-distortion			
	Overall loss	Misallocation	Entry-selection	
Benchmark	140.4	119.2	21.2	
Home close	124.2	118.7	5.4	

micro structure matters or not, we compute the ACR gain moving from a closed to an open equilibrium as inferred from the import share and an average full trade elasticity ϵ calculating the logarithmic percentage change in trade between the benchmark and Autarky and dividing this by the logarithmic percentage reduction in variable trade costs.

$$\text{ACR gain} = -\frac{1}{\epsilon} log(\text{domestic share}).$$

In our benchmark and in the data, the import share is 30.8%. The implied ARC gain from trade is therefore 12.7%, about 8.3 percentage points higher than in our model. Hence, only using aggregate data and ignoring firm-level distribution overestimates the gain from trade by 289%. Moreover, Foreign has a larger gain in the benchmark case—around doubling that of Home. But using the ACR formula, one would draw the opposite conclusion —that Foreign has a smaller gain than Home, 6.9% versus 12.7% since the import share of Foreign is about half of that of Home.

In terms of TFP our benchmark result shows that opening up leads to a 3% loss in TFP. In contrast, without distortion, TFP increases by 13.3%. Hence, contrary to the standard predictions, trade liberalization can exacerbate rather than improve resource allocation, causing a decline rather than a rise in TFP. As foreign has no distortions, the TFP levels are basically the same between the two models.

The lower panel of Table 6 reports the TFP losses from distortion for Home for the case of open and close. Not surprisingly, there are large TFP losses for Home country with domestic distortions. Eliminating these distortions would increase China's TFP by 124% under a close economy. The TFP losses are larger, 140% in the benchmark when China has more than 30% of import share. To understand the efficiency loss, we decompose them into a misallocation effect and an entry and selection effect. The majority of loss is still coming from misallocation, as the share of surviving firms is high. Nevertheless, there are non-negligible losses coming from the entry and selection margin.

5 Discussion

Measurement Error. Differences in measured average products need not imply differences in true marginal products. The presence of fixed costs in producing and exporting in our model, for instance, means that the average revenue products differ from the marginal revenue products. For this reason, a model estimation is used to back out the true dispersion in marginal products. Nevertheless, other types of mismeasurements in output and input may also generate a dispersion in the average revenue products, and thereby affect the measured TFPR— as shown in Bils, Klenow, and Ruane (2017) and Song and Wu (2015). In this section, we address the issues surrounding measurement error following the practices adopted in the literature.

The main approach involves using panel data to improve the estimates on the true marginal product dispersion, rather than simply employing cross-sectional data. With this method, we find that the measurement errors are small in China, accounting for only 18% of the variation in the average product.[5] This 18% includes the mismeasurement of production inputs in the presence of fixed cost, which is accounted for. We then reestimate our model and implied gains from trade using the adjusted dispersion of marginal product when measurement errors are corrected for. Our benchmark results are robust to this adjustment.

[5] In constrast, Bils, Klenow, and Ruane (2017) finds measurement errors can explain about half of variation of average products in Indian, and about 80% of that in the U.S.

5.1 Detecting measurement error

We exploit three alternative methods to detect measurement error: average annual observations within firms, first differences over years within firms, and covariance between first differences and average products. All three approaches point to the same conclusion: that 1) there is a large dispersion in marginal products in China; 2) measurement error only accounts for a small fraction of the dispersion in the measured marginal products (i.e. average products).

First, if measurement error were idiosyncratic across firms and over time, one can take the time average of annual observations within firms to wash out these errors, drastically reducing the dispersion of average products. The upper panel of Table 7 reports the statistics when we take the average within firms. The average standard deviation is 1.19 for the average marginal product of capital and 0.96 for the average marginal product of labor. The standard deviations of value added and the average product of inputs are 1.19 and 0.94, where the correlation between the two variables is 0.4. These results mimic our benchmark moments. In particular, the dispersions of average products of inputs are still high. This implies that measurement errors of the iid type cannot explain the observed dispersions in the average products.

Second, as pointed out by Bils, Klenow, and Ruane (2017), the dispersion of first differences reflect the true distortion if marginal products are constant over time. Calculating the first differences of value added $\triangle VA$, capital $\triangle K$, and labor $\triangle L$, and then taking the ratio $\triangle VA/\triangle K$ and $\triangle VA/\triangle L$ gives us an alternative measure of marginal products. The 1% tails of both ratios are trimmed, and the results are displayed in the middle panel of Table 7 for the year of 2001, 2004, and 2007. The dispersions are even higher than those in Table 1 for the standard measured marginal product of inputs using this measure.

Moreover, the alternative measured marginal products are highly correlated with our average products. Figure 1.11 plots the $\ln(\triangle VA/\triangle I)$ against the benchmark average product of input $\ln(VA/I)$ where I is the composite of inputs, $I = K^{\alpha}L^{1-\alpha}$, where each dot corresponds to one of 100 percentiles of $\ln(VA/I)$. The regression coefficient at the firm level is 0.72, see Table 8. Note that without measurement errors, the two measures are perfectly correlated. For the case with only measurement error, the two measures have no

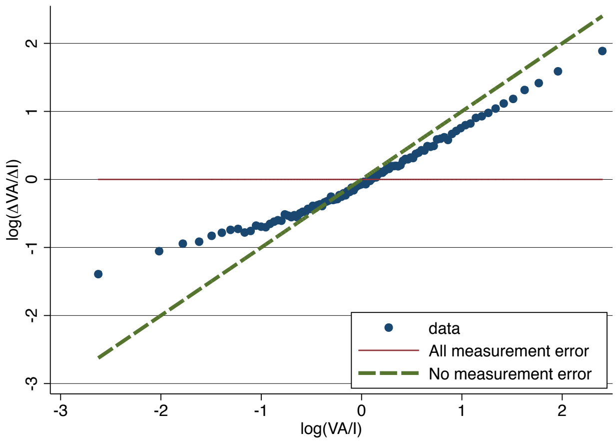
Table 7: Detecting Measurement Errors

Average annual observation within firm				
std(ln(APK))	std(ln(APL))	$std(lnVA)$	$std(ln(VA/I))$	$corr(lnVA, ln(VA/I))$
1.19	0.96	1.19	0.94	0.4
	First level differences			
	2001	2004	2007	
$std(ln(\triangle VA/\triangle K))$	1.82	1.78	1.76	
$std(ln(\triangle VA/\triangle L))$	1.68	1.60	1.61	
	Regression			
	Ψ	$\Psi(1-\lambda)$		
	0.53^{***}	-0.0997^{***}		
	(34.58)	(-20.65)		

Note: This table reports three ways to detect measurement errors.
The upper panel reports the average annual levels within firms.
The middle panel reports the ratio of first differences as another measure of marginal product, where $\triangle VA$ denotes the first difference of value added.
The lower panel reports regression coefficient as in equation (21).
Robust t-statistics in parentheses.

correlation. Hence, the high correlation between the alternative measure and the average products suggest small measurement errors and a large distortion-induced misallocation.

Figure 1.11: Measured Marginal Product using First Differences vs TFPR



Lastly, we follow Bils, Klenow, and Ruane (2017) and run the following regression to further quantify the extent to which measured average products reflect true marginal products:

$$\triangle \widehat{VA}_i = \Phi \cdot \log(TFPR_i) + \Psi \cdot \triangle \hat{I}_i - \Psi(1-\lambda) \cdot \log(TFPR_i) \cdot \triangle \hat{I}_i + D_s + \xi_i \qquad (21)$$

where $\triangle\widehat{VA}_i$ and $\triangle\hat{I}_i$ are the growth rate of measured value added and inputs respectively, and $\log(TFPR_i)$ is the measured average products. The underlying assumption here is that the measurement errors are additive. The variable of interest in the regression is λ, the variance of distortions relative to that of $TFPR$:

$$\lambda = \frac{\sigma^2_{\ln\tau}}{\sigma^2_{\ln(TFPR)}}.$$

The regression coefficient for Ψ is 0.53 and for the interaction of $\log(TFPR_i)$ and $\triangle\hat{I}_i$ is -0.0997. Both are significant, and the robust t-statistics are reported in Table 7. The implied λ is therefore 0.81. Hence, 81% of variation in $TFPR$ or average products is accounted for by distortion τ and 19% is due to measurement errors. The results are robust if we weight the observations with their share of aggregate value added or if we control for higher orders of $\ln(TFPR)$ to allow for stationary shocks to firms productivity and distortions. See the Appendix for details.[6]

In summary, the three alternative ways of sifting out measurement errors using panel data all point to the result that the dispersion in the average product of inputs are mainly driven by distortions rather than measurement error typically conceived.

6 Conclusion

This paper evaluates efficiency and welfare gains to trade in an economy with firm-level distortions. We find that the existence of distortions that drive differences in marginal products across firms substantially reduces the welfare gains to trade and may even bring about welfare and efficiency losses. For the case of China, trade gains are much lower than standard predictions based on observed trade flows and trade elasticities. There is

[6] Bils, Klenow, and Ruane (2017) also considers the following extension to allow for stationary shocks to firms productivity and distortions:

$$\begin{aligned}\triangle\widehat{VA}_i = {} & \Phi\cdot\log(TFPR_i) + \Psi\cdot\triangle\hat{I}_i - \Psi(1-\lambda)\cdot\log(TFPR_i)\\ & + \Gamma\cdot[\log(TFPR_i)]^2 + \Lambda(1-\lambda)\cdot[\log(TFPR_i)]^2\triangle\hat{I}_i\\ & + \Upsilon\cdot[\log(TFPR_i)]^3 + \Lambda(1-\lambda)\cdot[\log(TFPR_i)]^3\triangle\hat{I}_i.\end{aligned}$$

also a TFP loss rather than a significant TFP gain–which is at the core of the new trade theory models in which trade engenders a flow of resources towards the more productive firms. ACR formula suggests that one can abstract from micro-level distributions to estimate macro-level gains, fully inferred from observed variables on trade flows and trade elasticities. We show that firm-level distortions have large impact on trade gains. Further work can be done on evaluating how these wedges respond to trade liberalization. Our paper points to the fact that distortions may be an important factor determining countries' experiences with trade liberalization.

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Appendix

A. Proof for Proposition 2

Consider two symmetric countries with domestic and trade frictions. To derive Proposition 2, we use the following four equilibrium equations,

(a) Free entry condition:

$$P^{\sigma}Q\frac{1}{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}w^{1-\sigma}\left[\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau+\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau\right]$$
$$=\delta w f_e+wfH+wf_xH_x$$

(b) Price index:

$$P^{1-\sigma}=con_p\times\left[M_e\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau+M_e\tau_x^{1-\sigma}\int_{\varphi_x^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau\right]$$

where con_p is a constant depends on the model parameters.

(c) Cutoff of producing:

$$\varphi^*=con_v\times P^{-1}\left(PQ\right)^{\frac{1}{1-\sigma}}\tau^{\frac{\sigma}{\sigma-1}}$$

where con_v is a constant depends on the model parameters.

(d) Definition of domestic share λ:

$$\frac{1-\lambda}{\lambda}=\frac{\tau_x^{1-\sigma}\left[\int\int_{\varphi_x^*}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau\right]}{\left[\int\int_{\varphi^*}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau\right]}$$

Differentiating the above system of equations and using the relationship $d\ln Wel=d\ln(wL+T)-d\ln P$, we get Proposition 2 with the following definitions:

$$S_{\tau x}=\frac{\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}{\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau+\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}$$

$$\gamma_{\tau d} = \frac{\int (\varphi^*(\tau))^{\sigma-1} \tau^{-\sigma} g(\varphi^*(\tau),\tau)\varphi^*(\tau) d\tau}{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau}$$

$$\gamma_{\tau x} = \frac{\int (\varphi_x^*)^{1-\sigma} \tau^{-\sigma} g(\varphi_x^*,\tau)\varphi_x^*(\tau) d\tau}{\int \int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau}$$

$$\gamma_{x} = \frac{\int (\varphi_x^*(\tau))^{\sigma-1} \tau^{1-\sigma} g(\varphi_x^*(\tau),\tau)\varphi_x^*(\tau) d\tau}{\int \int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau}$$

$$\gamma_{d} = \frac{\int (\varphi^*(\tau))^{\sigma-1} \tau^{1-\sigma} g(\varphi^*(\tau),\tau)\varphi^*(\tau) d\tau}{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau}$$

$$\gamma_1 = (1 - S_{\tau x})\gamma_{\tau d} + S_{\tau x}\gamma_{\tau x} + S_{\tau x}\frac{\gamma_{\tau x} + \sigma - 1}{\gamma_x + \sigma - 1}(\gamma_d - \gamma_x)$$

B. Regressions for measurement errors

Table 8: Measured Marginal Products using First Differences vs TFPR

VARIABLES	(1) $\log(\frac{\triangle VA}{\triangle I})$	(2) $\log(\frac{\triangle VA}{\triangle I})$	(3) $\log(\frac{\triangle VA}{\triangle I})$
$\log(TFPR)$	0.718***	0.715***	0.718***
	(135.3)	(158.6)	(135.3)
Constant	1.410***	0.331***	1.410***
	(78.31)	(17.49)	(78.31)
Observations	624,659	624,699	624,659
R-squared	0.173	0.269	0.173
Time FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Specification (2) weights all the observations with the absolute value of composite input growth.
Specification (3) weights all the observations with the share of aggregate value added.

Table 9: Estimate Measurement Error

VARIABLES	(1) $\triangle\widehat{VA}$	(2) $\triangle\widehat{VA}$	(3) $\triangle\widehat{VA}$
$\log(TFPR)$	0.0376***	0.0144***	0.0616***
	(22.62)	(9.170)	(16.07)
$[\log(TFPR)]^2$			-0.0128***
			(-6.110)
$[\log(TFPR)]^3$			0.00152***
			(4.008)
$\triangle\widehat{input}$	0.530***	0.523***	0.524***
	(34.58)	(33.03)	(31.13)
$\log(TFPR) \times \triangle\widehat{input}$	-0.0997***	-0.0954***	-0.0893***
	(-20.65)	(-19.16)	(-6.420)
$[\log(TFPR)]^2 \times \triangle\widehat{input}$			-0.00611
			(-0.919)
$[\log(TFPR)]^3 \times \triangle\widehat{input}$			0.00108
			(1.040)
Constant	-0.0207***	0.0551***	-0.0241***
	(-3.125)	(8.231)	(-3.592)
Observations	1,106,982	1,106,914	1,106,982
R-squared	0.044	0.042	0.044
Time FE	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes

Robust t-statistics in parentheses

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

Specification (2) weights all the observations with the share of aggregate value added.