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ABSTRACT

This paper formalises a classic idea that in second-best environments trade can induce welfare losses: gains accrued can be outweighed by incremental income losses stemming from distortions. In a Melitz model with distortionary taxes, we derive sufficient statistics for welfare gains from trade, and show that its departure from the efficient case (ACR) can be captured by the gap between an input and output share and domestic extensive margin elasticities. The loss reflects the impact of an endogenous selection of more subsidized firms into exporting. We show sufficient conditions under which conventional formulas overestimate trade gains as well as conditions under which welfare losses can occur. Using Chinese manufacturing data, we demonstrate by taking into account firm-level distortions, welfare losses largely offset conventional gains to trade.

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The question of how much developing countries benefit from opening up to goods trade is a time-honoured subject. Much is now 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. Less clear, however, is why certain developing countries have benefited from trade more than others, and why certain countries have seemingly benefited less—or not much at all.[1] New trade theories suggest that developing countries have the most to gain from trade: if trade liberalization can induce the reallocation of resources from less to more productive firms, aggregate productivity and welfare will rise in turn.

But a universal truth is that developing countries are also subject to prevalent policy and institutional distortions. Examples include explicit and implicit taxes and subsidies to certain firms, industrial policies, export promotion policies and so forth—common themes in developing countries. Many believe that joining the WTO can potentially alleviate some of these problems as resources will flow to the more productive firms and more direct foreign competition drives out some of these inefficiencies. But how effective trade is in improving allocations that would lead to welfare gains is far from obvious, as alluded to by Rodríguez-Clare (2018), " [a] complication that may matter for the computation of the gains from trade is the presence of domestic distortions." This argument that trade may exert a different impact in a second-best environment has been an old-age question posed by Bhagwati and Ramaswami (1963). Even in classic textbook analysis, there are discussions on the "domestic market failure argument against trade", that " [when] the theory of second best [is applied] to trade policy..., imperfections in the internal function of an economy may justify interfering in its external economic relations" (Krugman, Obstfeld, and Melitz (2015)). This would be even more true in the case of developing countries.

These important questions animate the key motivation in this paper. To investigate, we incorporate firm-specific distortions into a two-country Melitz model and analyze welfare changes due to trade cost shocks. In our framework, firms differ in productivity as well in the level of distortions, which in the benchmark model, are assumed to be exogenous output wedges or factor wedges. These reflect various kinds of policy and institutional distortions and drive differences in the marginal products across firms.

[1]For example, Waugh (2010) shows, in a large sample of countries, that poor countries do not systematically gain more from trade.

We show that in an open economy with taxes, the first-order welfare impact of a productivity shock is equal to the sum of its direct effect, its indirect terms-of-trade impact, and an indirect fiscal externality. The first two effects are standard in the efficient case and in the absence of distortions, can be summarized with the formula developed by Arkolakis, Costinot, and Rodríguez-Clare (2012) (henceforward ACR). The fiscal externality captures how distortions affect market selection and how much firms produce—thus, the aggregate fiscal revenue and income. This fiscal externality is negative if there is an increase in overall subsidy on firms, and positive if there is an increase in overall tax. This negative externality can weigh down on the conventional gains accrued, and under certain conditions, lead to a welfare loss to trade. Thus, a main theoretical result is to provide sufficient statistics for welfare gains/losses to trade in this inefficient economy, and show that statistics such as trade flows and elasticity are no longer sufficient to capture the welfare changes. The main departure from ACR can still be summarized by sufficient statistics—the gap between a domestic sales share and input share, and domestic extensive elasticities.

Distortions (for instance, tax and subsidies) now 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. A mass of highly subsidized but not adequately productive firms could 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 brings about gains in the Melitz-type model is no longer based solely on productivity; it is determined jointly by firm productivity and distortions. And it is now possible that overall subsidies would rise with more trade, leading to a negative fiscal externality.

Trade cost shocks can affect overall taxes/subsidies through market selection; and its general equilibrium impact influences firm-level production. Despite the complexity involved with these heterogeneous effects, our theoretical analysis demonstrates that it is still possible to summarize the fiscal externality effect with sufficient statistics. We show that one can infer a negative selection (of more subsidized firms) into exporting if there is a larger fall in the domestic input share than the sales share, and a negative selection into the domestic market if the gap between the input and output elasticity (with respect to the domestic cutoff) lead to higher subsidy in the domestic market with trade. In this case, trade induces some labor to be allocated to the export sector, and the input share used to produce for exports exceeds the export revenue share, hence exporters are relatively more subsidized, which entails larger subsidies than domestic production. In addition, trade induces an increase in the domestic cutoff, the domestic extensive elasticities determine whether the domestic market also selects more subsidized firms, hence reduces the tax revenue accrued in the domestic market. Thus, trade causes production to be more subsidized than before—and induces a negative fiscal externality.

The same idea applies to an economy moving from autarky to a fully open economy. If opening up induces an increase in subsidies for the domestic market compared to autarky, and selling to the foreign market entails more subsidies than selling to the domestic market, then there is a rise in fiscal subsidies. This is most clearly seen in a special case—where productivity is homogenous across firms, but domestic distortions are Pareto-distributed. Selection in this instance is completely driven by distortions, and the fiscal externality of opening up is always negative, dominating the decline in the price index. Hence, there is always a welfare loss when opening up to trade. In more general cases, we derive a sufficient condition for a negative fiscal effect, and show that it is more likely to occur if the dispersion of wedges are relatively larger than that of productivity, and if the wedges and productivity are less correlated. In this case, selections are more affected by wedges.

One of the prominent ideas that trade can induce welfare losses is that there could be immiserizing-growth in the presence of distortions: Bhagwati (1968) and Johnson (1967) show that the gains from technical growth in a tariff-protected import-competing industry can be outweighed by the incremental loss of real income due to distortions in the post-growth situation vs. the pre-growth situation. Newbery and Stiglitz (1984) show that in risky economies with no insurance markets, free trade may be Pareto inferior to no trade. A key distinguishing feature of our work is casting the problem in a new trade model setting, and to express the first-order welfare effect in the presence of taxes as a function of a few sufficient statistics.

Another distinguishing feature is to quantify these effects. As such, we operationalize our results in the context of China. We choose China because it is an economy with many distortions,[2] and one that has experienced an important trade liberalization event in the early 2000s. In our quantitative analysis, we expand upon the basic framework to incorporate additional wedges in exporting market. We use micro data from Chinese manufacturing and examine how much departure there is between our model and the standard trade models without pre-existing domestic distortions. We find that when taking into account distortions, for China, negative externality led to a welfare loss of 15%, more than offsetting the conventional ACR gains of 11%.

It is important to point out that in the quantitative analysis, we do not measure wedges directly. The reason is that the *observed* statistics are not the *underlying* ones: existing firms have been subject to selection, and thus their observed distributions are not the true ones. The same reasoning goes for the observed correlation between productivity and wedges as a heavily taxed firm must have high productivity to survive or export. For these reasons, the approach adopted in the quantitative exercises is to estimate the underlying joint distribution of wedges and productivity, and costs of producing and exporting so as to match the observed patterns of firms' outputs, inputs, and exports.

What makes our paper different from the seminal works of Hsieh and Klenow (2009) (henceforward HK), Baily, Hulten, and Campbell (1992), Restuccia and Rogerson (2008), Bartelsman, Haltiwanger, and Scarpetta (2009) is first of all, the open economy nature of our model, and secondly, the endogenous mechanism of entry/exit and the attendant firm selection effect. Yang (2021) pointed out the importance of endogenous entry and selection in a distorted HK closed economy, while we focus on the trade effects with firm-level distortions. Empirical works have also demonstrated the importance of entry and exit for

[2] Examples include implicit subsidies such as soft budget constraints, favorable costs of capital, preferential tax treatments and implicit guarantees. Firms with political connections having access to special deals and receiving substantial benefits are also widely documented (see Guo, Jiang, Kim, and Xu (2013) and Bai, Hsieh, and Song (2019)). Wu (2018) conducts an empirical analysis and finds that policy distortions can be explained by investment-promoting programs that favor such firms. A body of work has shown that idiosyncratic distortions explain the majority of the dispersion in marginal products. Wu (2018) finds that policies account for the majority of the observed misallocation of capital, as opposed to financial frictions. Using a different approach and modeling framework, David and Venkateswaran (2017) find also that firm-specific distortions, rather than technological or information frictions, account for the majority of the observed dispersions in marginal products. Bai, Lu, and Tian (2018) disciplines financial frictions with firms' financing patterns, sales distribution, and change of capital. They find that financial frictions cannot explain the observed relation between firms' measured distortions and size.

China's growth.[3]

In this framework, the positive firm selection is the central driving force for gains to trade. As such, it abstracts from other types of gains to trade, such as trade-induced technological diffusion (Alvarez, Buera, and Lucas Jr (2013) and Buera and Oberfield (2016)), adoption (Perla, Tonetti, and Waugh (2015) and Sampson (2015)) and innovation (Atkeson and Burstein (2010)). While these mechanisms in principle work to increase the gains to trade, with its quantitative significance a subject to debate,[4] it does not detract from the fact that the distortionary impact on allocation efficiency still induces large welfare losses, which is what we are interested in. Of course, distortions can also interact with some of these additional channels. For instance, in a model with firm innovation, one would need to consider the fact that distortions affect not only production decisions but potentially also innovation decisions. Policy distortions can be introduced to serve other purposes, a consideration that is important but beyond the scope of this paper. We also do not consider how trade can reduce domestic distortions, for example, if concurrent domestic reforms are requisite for joining the WTO or if quotas are removed (see Khandelwal, Schott, and Wei (2013)). However, in our quantitative analysis, we do allow for firms to face a different distribution of distortions when they export and examine welfare gains therein.

Taken together, our quantitative analysis is meant to highlight the first-order effects of a particular channel—distortionary effect of firm selection, and also to compare it with benchmark results in the workhorse models of international trade. An implication of this paper is that in order for developing countries to reap the full gains of trade, simultaneous or antecedent domestic reforms aimed at reducing policy distortions may be crucial.[5]

[3] Brandt, Van Biesebroeck, and Zhang (2012) find that net entry accounts for roughly half of Chinese manufacturing productivity growth. The creation and selection of new firms in China's non-state sector has been particularly important.

[4] Perla, Tonetti, and Waugh (2015) and Atkeson and Burstein (2010), for instance, find that trade gains are not too different from ACR gains. In Perla, Tonetti, and Waugh (2015), there are trade-induced within-firm productivity improvements. However, their aggregate growth effects come with costs—losses in variety and reallocation of resources away from goods production. Thus, the aggregate effect on welfare is similar to ACR gains. Atkeson and Burstein (2010) show that general equilibrium effects limit the first-order effects on aggregate productivity even when there is firm-level innovation.

[5] The policy implication drawn from this framework is consistent with works indicating that policies aimed to neutralize domestic distortions may be complementary to trade liberalization (Chang, Kaltani, and Loayza (2009) and Harrison and Rodríguez-Clare (2010)).

1 Theoretical Framework

1.1 Baseline Model

The world consists of two large open economies, Home and Foreign, with heterogeneous firms. The two economies can differ in the size of labor and distribution of firms. Labor 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 the budget constraint

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

where P is the price of final goods, L is labor, w is wage rate, 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. A CES production function implies that aggregate output Q and price index P take the form

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

where σ is the elasticity of substitution across intermediate goods, Ω is the endogenous set of goods, $p(\omega)$ is the price of good ω in the market. The individual demand for the good is thus given by

$$q(\omega) = \left(\frac{p(\omega)}{P}\right)^{-\sigma} Q. \tag{2}$$

Henceforward, ω is suppressed for convenience.

Intermediate Goods Producers. There is a competitive fringe of potential entrants (in both countries) 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 revenue earned.[6] Once the sunk entry cost is paid, a firm draws its productivity φ and τ independently from a joint

[6] It is equivalent to an input wedge on all the input a firm uses.

distribution, $g(\varphi, \tau)$ over $\varphi \in (0, \infty), \tau \in (0, \infty)$.[7] Firms are monopolistically competitive. Those that sell domestically solve

$$\max_{p,q} \ \frac{pq}{\tau} - \frac{w}{\varphi}q - wf. \tag{3}$$

Production of q units entails fixed cost of production f and constant variable costs such that total labor required is $\ell = f + q/\varphi$.[8] If firms decide to export, they face a fixed exporting cost of f_x units of labor and iceberg variable costs of trade $\tau_x > 1$ such that the exporting firm's problem is

$$\max_{p_x, q_x} \frac{p_x q_x}{\tau} - \frac{w}{\varphi}\tau_x q_x - w f_x,$$

where foreign demand is $q_x = \left(p_x / P_f\right)^{-\sigma} Q_f$, with P_f and Q_f denoting the aggregate price index and demand abroad. Firms with the same productivity and distortion behave identically, and thus we can index firms by their (φ, τ) combination. Let the optimal production and profit for domestic market be $q(\varphi, \tau)$ and $\pi(\varphi, \tau)$ and for the foreign market be $q_x(\varphi, \tau)$ and $\pi_x(\varphi, \tau)$.

Given the fixed cost of production, there is a zero-profit cutoff productivity below which firms would choose not to produce, or service the foreign market.[9] The cutoff productivities for servicing the domestic and foreign markets are

$$\varphi^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{wf}{P^\sigma Q}\right]^{\frac{1}{\sigma-1}} w\tau^{\frac{\sigma}{\sigma-1}}, \qquad \varphi_x^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{w f_x \tau_x^{\sigma-1}}{P_f^\sigma Q_f}\right]^{\frac{1}{\sigma-1}} w\tau^{\frac{\sigma}{\sigma-1}}. \tag{4}$$

These 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

[7] The model equilibrium is equivalent to a stationary equilibrium of a model allowing for the constant exogenous probability of death δ and entry cost f_e/δ.

[8] We can easily extend the production to include capital, i.e. $k^\alpha \ell^{1-\alpha}$. 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 simple model, we introduce one heterogeneous distortion at the firm level, and our τ is an output distortion, it includes all input distortions that increase the marginal products of capital and labor by the same proportion as an output distortion. In our quantitative exercises, we include both capital and labor and also extend the model to consider heterogeneous distortions in foreign markets that could be different from those in the domestic market.

[9] Equilibrium price is the standard result $p = [\sigma/(\sigma-1)]\,(w\tau/\varphi)$, and thus domestic producing firm profits are $\pi(\varphi,\tau) = \sigma^{-\sigma}(\sigma-1)^{\sigma-1} P^\sigma Q w^{1-\sigma} \varphi^{\sigma-1} \tau^{-\sigma} - wf$. If firms export, the optimal export price is $p_x = [\sigma/(\sigma-1)]\,(w\tau_x\tau/\varphi)$, and exporting profits are $\pi_x(\varphi,\tau) = \sigma^{-\sigma}(\sigma-1)^{\sigma-1} P_f^\sigma Q_f (w\tau_x)^{1-\sigma} \varphi^{\sigma-1}\tau^{-\sigma} - wf_x$.

and survive if sufficiently subsidized.

The government's budget is balanced so that the lump-sum transfers is given by

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

where the endogenous set of goods Ω_H includes Home firms goods selling to both domestic and foreign markets.

Equilibrium Conditions. The equilibrium features a constant mass of entrants M_e and producers M, along with an ex-post distributions of productivity and distortion among operational firms $\mu(\varphi, \tau) = g(\varphi, \tau) / \int \int_{\varphi^*(\tau)}^{\infty} g(\varphi, \tau) \, d\varphi d\tau$ if $\varphi \geq \varphi^*(\tau)$; and $\mu(\varphi, \tau) = 0$ otherwise. The probability of successful entry is $\omega_e = \int \int_{\varphi^*(\tau)}^{\infty} g(\varphi, \tau) \, d\varphi d\tau$, and of exporting conditional on entry is $\omega_x = \int \int_{\varphi_x^*(\tau)}^{\infty} \mu(\varphi, \tau) \, d\varphi d\tau$. In equilibrium, the measure of producing firms equals the product of the measure of entrants and the probability of entering: $\omega_e M_e = M$.

Foreign economy has a distribution $g_f(\varphi, \tau)$ on productivity and distortion. Its measure of entrants and producers are given by M_{ef} and M_f, the cutoff productivities are $\varphi_f^*(\tau)$ and $\varphi_{xf}^*(\tau)$, and its ex-post distributions of operational firms is $\mu_f(\varphi, \tau)$.

In equilibrium, the Home price index P satisfies:

$$P = \frac{\sigma}{\sigma - 1} \left[M \int \int_{\varphi^*(\tau)}^{\infty} \left(\frac{w\tau}{\varphi}\right)^{1-\sigma} \mu(\varphi, \tau) \, d\varphi d\tau + M_f \int \int_{\varphi_{xf}^*(\tau)}^{\infty} \left(\frac{w_f \tau_x \tau}{\varphi}\right)^{1-\sigma} \mu_f(\varphi, \tau) \, d\varphi d\tau \right]^{\frac{1}{1-\sigma}}. \tag{5}$$

Another key equation is the free entry condition:

$$\int \int_{\varphi^*(\tau)} \pi(\varphi, \tau) g(\varphi, \tau) d\varphi d\tau + \int \int_{\varphi_x^*(\tau)} \pi_x(\varphi, \tau) g(\varphi, \tau) d\varphi d\tau = w f_e, \tag{6}$$

which, combined with labor market clearing implies an equation for the measure of producing firms:

$$M = \frac{L}{\sigma \left(\frac{f_e}{\omega_e} + f + \omega_x f_x\right)}. \tag{7}$$

The equilibrium conditions of price index P_f, free entry, and labor market clearing in Foreign take similar forms as those in Home. In addition, the assumption of balanced trade yields

$$P_f^\sigma Q_f M \int \int_{\varphi_x^*(\tau)}^{\infty} \left(\frac{w\tau_x\tau}{\varphi}\right)^{1-\sigma} \mu(\varphi,\tau)\, d\varphi d\tau = P^\sigma Q M_f \int \int_{\varphi_{xf}^*(\tau)}^{\infty} \left(\frac{w_f\tau_x\tau}{\varphi}\right)^{1-\sigma} \mu_f(\varphi,\tau)\, d\varphi d\tau. \tag{8}$$

Normalizing the Home country wage rate to 1, there are eleven equations, the two zero cutoff productivities for domestic production and exporting (4), the definition of price indices (5), the free entry conditions (6), the labor market clearing condition (7) and all of their Foreign counterparts, along with a goods market clearing/balanced trade equation (8). These equations yield the equilibrium consisting of eleven unknowns $\{\varphi^*(\tau), \varphi_x^*(\tau), \varphi_f^*(\tau), \varphi_{xf}^*(\tau), P, P_f, Q, Q_f, M, M_f, w_f\}$. A detailed derivation of the model is provided in Appendix A.

Proposition 1. *The allocations, entrants, and cutoff functions* $\{\varphi^*(\tau), \varphi_x^*(\tau), \varphi_f^*(\tau), \varphi_{xf}^*(\tau), Q, Q_f, M, M_f\}$ *are homogeneous of degree zero in mean wedge* $\bar{\tau}$. *Prices* $\{P, P_f, w_f\}$ *are homogeneous of degree one in* $\bar{\tau}$, *i.e.* $P(\bar{\tau}_1)/P(\bar{\tau}_2) = \bar{\tau}_1/\bar{\tau}_2$, *and similarly for* P_f *and* w_f.

The proposition shows that increasing the mean of the exogenous wedges does not affect real variables. Hence, the misallocation of resources arises from heterogeneous wedges across firms rather than changes to the average wedge.

2 Theoretical Comparative Static

This section delivers our theoretical welfare decomposition in response to an iceberg trade cost shock. Section 2.1 shows that with heterogeneous wedges, the general welfare formula includes an extra term reflecting distortions, in addition to the standard ACR term. Section 2.2 links the distortions to some sufficient statistics. Section 2.3 explores special cases with sufficient conditions for welfare loss after trade.

2.1 Welfare with distortions

Welfare, denoted as W, is evaluated using final consumption per capita C/L, which equals Q/L in equilibrium. Simple algebra has it that $Q/L = (PQ/L)(1/P)$, where PQ/L is the revenue-based total factor productivity of the economy, i.e. $PQ/L = \overline{TFPR}$. Using the price index (5) and the balanced trade condition (8), we get an expression for welfare,

$$W = \frac{\sigma-1}{\sigma} M_e^{\frac{1}{\sigma-1}} \left[\int \int_{\varphi^*(\tau)} \left(\varphi \frac{\overline{TFPR}}{MRPL_\tau} \right)^{\sigma-1} dG + \frac{P_f^\sigma Q_f}{P^\sigma Q} \int \int_{\varphi_x^*(\tau)} \left(\frac{\varphi}{\tau_x} \frac{\overline{TFPR}}{MRPL_\tau} \right)^{\sigma-1} dG \right]^{\frac{1}{\sigma-1}}, \tag{9}$$

where $MRPL_\tau = w\tau$ is the firm-specific marginal revenue product of labor. This expression shows that welfare is related to weighted firm productivity using relative distortions as weights. In an efficient case without distortions, all firms have the same marginal revenue product, $MRPL_\tau = \overline{TFPR} = w$. With firm-level tax, the source of welfare loss here can arise from a misallocation of resources, captured by dispersions in $\overline{TFPR}/MRPL_\tau$, and a misallocation caused by selection and entry mechanisms captured by M_e, φ^*, φ_x^* being different from their respective efficient levels.

Welfare change due to trade We next derive an expression for welfare change in response to an iceberg cost shock as a function of a small number of sufficient statistics. In effect, this extends ACR results to a model with inefficiencies.

The change in welfare results from changes in consumer prices 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). We label this change in lump-sum transfer from a trade cost shock as a *fiscal externality*. Specifically, the welfare change $d\ln W$ from a small trade cost change can be written as

$$d\ln W = d(Q/L) = -d\ln P + d\ln(PQ/L) = -d\ln P + d\ln(1+T), \tag{10}$$

where we substitute PQ with $wL + T$ using the households' budget constraint (1), zero profit $\Pi = 0$, and normalization $w = L = 1$. Here $d\ln(1+T)$ or $d\ln PQ$ measures the fiscal externality.[10]

[10]In general, changes to income could include other general equilibrium effects. For instance, if entry is restricted so that $d\ln M_e = 0$, the change to $PQ = wL + \Pi + T$ includes both fiscal externality and profit change. In this case, $d\ln PQ/L$ still represents $d\ln \overline{TFPR}$ and can be summarized by our sufficient statistics with small changes from total variable labor to total labor.

In an efficient case without wedges, the transfer T is 0, and $d\ln W = -d\ln P$. As in ACR, the direct and indirect terms-of-trade effect on prices arising from trade cost shocks can be summarized by sufficient statistics—the change in domestic expenditure share (or trade flows) and the trade elasticity.[11]

In our model, the lump sum transfer T equals the sum of output wedges faced by firms, $T = \int \frac{\tau_i - 1}{\tau_i} p_i q_i di$. This transfer is positive if the wedges impose an overall tax on firms in equilibrium and negative if they imply an overall subsidy. In addition, the revenue-based total factor productivity is linked to this lump-sum transfer as $\overline{TFPR} = PQ/L = 1 + T$.

When a trade shock occurs, it directly affects the fiscal externality through T because it determines which firms produce and pay taxes. In addition, the trade shock has an impact on consumer prices, not only through the direct and indirect effects of terms of trade, but also through the impact of fiscal externality on total spending, hence on the endogenous selection of firms. Therefore, conventional statistics such as trade flows and elasticity are no longer sufficient to capture the changes in prices resulting from these factors.

In what follows, we show that despite the complexity of the model with inefficiencies and its interweaving mechanisms, we can do a similar exercise as in ACR and derive sufficient statistics for welfare changes. Starting with a few definitions, let λ be the *domestic sales share*, which is the share of home-country expenditure on domestically produced goods—-also the proportion of domestic sales in total sales:

$$\lambda = \frac{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau}{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau + \frac{P_f^\sigma Q_f}{P^\sigma Q} \tau_x^{1-\sigma} \int \int_{\varphi_x^*(\tau)} \varphi^{\sigma-1} \tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau}, \qquad (11)$$

and S be the *domestic input share*, which is the share of the total variable labor employed by

[11] Arkolakis, Costinot, and Rodríguez-Clare (2012) demonstrate that in the absence of distortions, welfare changes across a wide class of models can be inferred using these two variables. Conditional on observed trade flows and an estimated trade elasticity, the welfare predictions are the same in a wide class of models with different micro-level predictions and sources of welfare gains, or structure interpretations of the trade elasticity. Melitz and Redding (2015) show, however, that under more general distribution functions for productivity, the trade elasticity is no longer invariant to trade costs and across markets, and therefore no longer a sufficient statistic for welfare. Micro-level information becomes necessary.

domestic firms that goes towards production for the domestic market,

$$S = \frac{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau}{\int \int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau + \frac{P_f^\sigma Q_f}{P^\sigma Q}\tau_x^{1-\sigma} \int \int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau}. \tag{12}$$

It is easy to see from the above two definitions that without distortions, $S = \lambda$. With distortions, a firm's variable labor is not proportional to its sales, and so S and λ are not the same.

As in Arkolakis, Costinot, and Rodríguez-Clare (2012) and Melitz and Redding (2015) (henceforth MR), a concept capturing the extensive margins in each market is

$$\gamma_\lambda(\hat{\varphi}) = -\frac{d\ln\left[\int \int_{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}} \varphi^{\sigma-1}\tau^{1-\sigma} g(\varphi,\tau) d\varphi d\tau\right]}{d\ln\hat{\varphi}}, \quad \gamma_s(\hat{\varphi}) = -\frac{d\ln\left[\int \int_{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}} \varphi^{\sigma-1}\tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau\right]}{d\ln\hat{\varphi}}, \tag{13}$$

where $\gamma_\lambda(\hat{\varphi})$ denotes the elasticity of the cumulative sales of firms above any cutoff $\hat{\varphi}$ within a market, with respect to the cutoff. In this setup with distortions, there is also a $\gamma_s(\hat{\varphi})$, which is the elasticity of the cumulative variable labor of firms above any cutoff $\hat{\varphi}$ within a market, with respect to the cutoff.

In the analysis below, we consider a fall in trade costs in an open economy equilibrium. Substituting the trade balance condition (8) into the price index equation (5), and the labor market condition (7) into the free entry condition (6), while combining the differentiation of the two conditions yield a general representation of welfare.

Proposition 2. ***(General Welfare Expression)*** *The change in welfare associated with an iceberg cost shock is*

$$d\ln W = \underbrace{\frac{1}{\gamma_\lambda + \sigma - 1}[-d\ln\lambda + d\ln M_e]}_{(ACR/MR)} + \underbrace{\left(\frac{\gamma_\lambda/(\sigma-1)}{\gamma_\lambda+\sigma-1} + 1\right) d\ln PQ}_{(distortion)}, \tag{14}$$

where the fiscal externality, equal to $d\ln PQ$, can be further summarized by

$$d\ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}[-d\ln\lambda + d\ln M_e] + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)(-d\ln\lambda + d\ln S). \tag{15}$$

PROOF: Appendix B.1.

This welfare expression establishes the departure from ACR/MR. We define the second term to be associated with 'distortions' since it represents the overall discrepancy when using ACR sufficient statistics to measure welfare gains in a world where there are inefficiencies. When there are no wedges, the domestic output share coincides with the domestic input share, $\lambda = S$, and the two elasticities are the same, $\gamma_\lambda = \gamma_s$, hence there is no fiscal externality, $d \ln PQ = 0$. When the fiscal externality term is negative, ACR tends to overstate welfare gains.

Note that the distortion term includes a multiplier, i.e. $\frac{\gamma_\lambda/(\sigma-1)}{\gamma_\lambda+\sigma-1} + 1$, in front of the fiscal externality. Hence, if the fiscal externality is negative, the distortion becomes even more negative, leading to a further reduction in welfare. This multiplier reflects our previous discussion that firm-level distortions affect not only the lump-sum transfer T, but also consumer prices in the welfare equation (10).

2.2 Fiscal externality

In this section, we unpack the significance and meaning of the welfare expression, by showing how the change in fiscal externality links to the endogenous adjustment of λ, S and elasticities. Intuitively, when a country opens up to trade or is subject to a trade shock, whether fiscal subsidies to firms increase or fall depends on two forces: (1) whether selling to the foreign market entails more subsidies than selling to the domestic market, and (2) whether there is an increase in subsidies incurred in the domestic market compared to before.

The first force can be determined by comparing $d \ln S$ and $d \ln \lambda$. If exports require a larger input share than their sales share when there is more trade, i.e. $d \ln S < d \ln \lambda$, the country is subsidizing relatively more their sales to foreign markets than to domestic markets. This gives rise to a negative fiscal externality and reduced welfare. The second force is linked to the relative elasticity of γ_s and γ_λ. When $\gamma_s < \gamma_\lambda$, a small increase in the domestic cutoff decreases output relative to labor in the domestic market as compared to before, and the surviving firms are those receiving relatively more subsidies, which reduces tax revenue from domestic sales and generates negative fiscal externalities.

To see this, start with the aggregation for PQ and L. Under the balanced trade condition, total expenditure equals total revenue, which implies

$$PQ = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} M_e \left[P^{\sigma} Q \iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG + P_f^{\sigma} Q_f \tau_x^{1-\sigma} \iint_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG\right], \quad (16)$$

where the first part is the domestic sales and the second part is the foreign sales subject to foreign demands, and iceberg trade cost τ_x. Under the free entry condition, the total fixed cost is proportional to the total variable labor. We can therefore write the labor market condition as

$$L = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} M_e \left[P^{\sigma} Q \iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG + P_f^{\sigma} Q_f \tau_x^{1-\sigma} \iint_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG\right], \quad (17)$$

where the first part is proportional to variable labor used to produce domestic demand, and the second part is proportional to variable labor for producing foreign demand.

Now with equations (16), (17) and definitions of λ and S, we can express the lump-sum transfer to households as $1 + T = PQ/L = \frac{S}{\lambda} \frac{\iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG}{\iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG}$, which implies

$$d\ln(1+T) = (-d\ln\lambda + d\ln S) + [\gamma_s(\hat{\varphi}^*) - \gamma_\lambda(\hat{\varphi}^*)] d\ln\hat{\varphi}^*, \quad (18)$$

where γ_s and γ_λ are evaluated at $\hat{\varphi}^*$ in equation (13). The above equation shows that the change in λ and S and the elasticities of γ_s and γ_λ are key to inferring the fiscal externality. Mechanically, γ_s and γ_λ affect the fiscal externality because of the selection in the domestic market. If the distribution of domestic production firms is fixed, i.e. $d\ln\hat{\varphi}^* = 0$, these elasticities will not affect the fiscal externality.

The fiscal externality, as we know, is the after-trade change in $1 + T = (wL + T)/L$. A lower T implies a smaller tax revenue or a larger subsidy in the production sector, and a lower income and welfare. We can write the income per capita as a weighted average of sales per input in foreign and domestic production, i.e.,

$$\frac{wL + T}{L} = \frac{\sigma-1}{\sigma}\left(\frac{P_x Q_x}{L_{vx}} \frac{L_{vx}}{L_v} + \frac{P_d Q_d}{L_{vd}} \frac{L_{vd}}{L_v}\right), \quad (19)$$

where the equality holds because the variable labor L_v is proportional to the total labor L due to the free entry condition $L_v = \frac{\sigma-1}{\sigma}L$, and the total income (labor) can be split into foreign and domestic income (labor), i.e., $wL + T = (wL_x + T_x) + (wL_d + T_d)$ and $L_v = L_{vx} + L_{vd}$. In addition, we use the equilibrium conditions that expenditure equals income in each market, i.e., $wL_x + T_x = P_x Q_x$ and $wL_d + T_d = P_d Q_d$.

According to equation (19), whether tax revenue increases or decreases after trade depends on the relative change in sales per input in the foreign and domestic production—$P_x Q_x / L_{vx}$ and $P_d Q_d / L_{vd}$; and the change in domestic sale per input relative to before trade, i.e., the change of $P_d Q_d / L_{vd}$. Hence, when trade induces a lower $P_x Q_x / L_{vx}$ than $P_d Q_d / L_{vd}$, it causes tax revenues to be smaller or subsidies to be larger in the foreign market compared to the domestic one. And when trade induces a lower $P_d Q_d / L_{vd}$, it further lowers tax revenue from domestic production than before.

Turning to Force (1) to infer the subsidies used for foreign vs. domestic market, first note that $S < \lambda$ is equivalent to

$$\frac{\int\int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG}{\int\int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG} < \frac{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG}{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG}.$$

The left-hand side is proportional to the ratio of total sales to input used for export production, i.e., $\frac{\sigma-1}{\sigma}\frac{P_x Q_x}{L_{vx}}$, whereas the right-hand side is proportional to the sales-input ratio in the domestic market, $\frac{\sigma-1}{\sigma}\frac{P_d Q_d}{L_{vd}}$. Hence,

$$S < \lambda \Rightarrow \frac{P_x Q_x}{L_{vx}} < \frac{P_d Q_d}{L_{vd}}. \tag{20}$$

Equations (19) and (20) reveal how S and λ provide information on the fiscal externality or total subsidy to firms. In a closed economy, both $\ln S$ and $\ln \lambda$ are equal to zero. Therefore, when the economy opens up to trade from an autarky stage, $d \ln S = \ln S_{open}$ and $d \ln \lambda = \ln \lambda_{open}$. Equation (20) shows that if $S_{open} < \lambda_{open}$, then $\frac{P_x Q_x}{L_{vx}} < \frac{P_d Q_d}{L_{vd}}$ after the economy opens to trade. Thus, when trade shifts more labor toward exports, production used for exports receives more subsidies than domestic production, causing $wL + T$ and welfare to fall. This negative impact is reflected as $-d \ln \lambda + d \ln S < 0$ in equation (15) and (18).

Now turning to Force (2) to infer the changes to subsidies in the domestic market, recall that the domestic tax revenue (or subsidy) is associated with domestic $P_d Q_d / L_{vd} = \frac{\sigma}{\sigma-1} \frac{\iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG}{\iint_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG}$. Taking derivatives, the change of domestic sales per input is given by

$$d \ln \left(\frac{P_d Q_d}{L_{vd}} \right) = [\gamma_s(\hat{\varphi}^*) - \gamma_\lambda(\hat{\varphi}^*)] d \ln \hat{\varphi}^*.$$

Trade causes a change in domestic cutoffs $\hat{\varphi}^*$, which subsequently impacts domestic tax revenue when there is a discrepancy between the elasticities of γ_s and γ_λ. In particular, if trade induces an increase in production cutoff $d \ln \hat{\varphi}^* \geq 0$ and $\gamma_s \leq \gamma_\lambda$, domestic production becomes relatively more subsidized than before trade.

It is clear that the open-economy scenario is complex, as trade affects firms in different ways: while some domestic producers are not directly impacted by trade costs, some firms enter into exporting or exit production. Trade costs have a bearing on taxes/subsidies due to market selection $\varphi(\tau), \varphi_x(\tau)$, as well as general equilibrium effects, P, Q, P_f, Q_f, and M_e, which in turn affect each firm's production and taxes. Despite these heterogeneous effects, we can summarize the impact on fiscal externality by comparing subsidies for exports and domestic production and the before and after subsidies for domestic production. Furthermore, we show that these relative subsidies can be summarized by the change in the gap between trade input and sales share and the domestic elasticity of sales and labor at the cutoff.

2.3 Special Cases

To understand the circumstances in which trade leads to a negative fiscal externality and a decrease in welfare, we analyze several special cases to clarify the underlying mechanism. We establish the conditions under which ACR overestimates the welfare gain from trade—i.e. the distortion term in equation (14) is negative. Furthermore, we provide sufficient conditions for an overall reduction in welfare resulting from trade.

Corollary 1. ***(Welfare Loss)*** *Under homogenous productivity and Pareto-distributed domestic wedge $1/\tau$ with parameter θ, $d \ln W = \frac{\sigma}{\sigma-1} [d \ln S - d \ln \lambda]$ and*

1. *Moving from a closed economy to an open economy always entails a welfare loss, as $S < \lambda$ for*

any open economy.[12]

2. *In the open-economy equilibrium, for a small change of trade cost, the distortion term is always negative, i.e., using ACR overestimates welfare gains.*

PROOF: Appendix B.2.

With homogenous productivity, the efficient allocation is that either all firms export or none of them export—firms have identical market shares in both input and output markets. However, with distortions, the relatively subsidized firms produce more than others, with the dispersion of sales (employment) reflecting the distortions. Trade further exacerbates misallocation as the relatively subsidized firms export and expand, which makes these firms use more labor relative to their output, showing up as $S < \lambda$ for domestic firms in any open economy.

Corollary 1 highlights two key points under the special case. The first point compares the welfare of an open economy to a closed one. The open economy always has lower welfare because $S < \lambda$ and technological gains from trade are outweighed by the losses arising from the deterioration in resource allocation.

The second point in Corollary 1 focuses on the impact of a local change in trade costs. Here, the distortion term is always negative. However, it is worth noting that the local welfare change of transitioning from high to low trade costs may not always be negative. When the current trade cost is high, a reduction in trade cost can lead to a welfare loss. Conversely, when the current trade cost is low, further reduction in trade cost can result in a welfare gain. The reason is that misallocation, showing up in the negative distortion term, matters more when trade begins to select some firms to export. As trade costs decrease and more firms engage in export, the impact of firm selection becomes less significant. As a result, the price gain outweighs the fiscal losses, and the welfare starts to increase. Nonetheless, the welfare under any open economy is always lower than that in autarky.

Corollary 2. *Suppose (τ, φ) are jointly log-normal with standard deviations of σ_τ and σ_φ and correlation ρ. When $\sigma_\tau \geq \frac{\sigma-1}{\sigma}\rho\sigma_\varphi$, then $S \leq \lambda$ and $\gamma_s \leq \gamma_\lambda$ at any cutoff. Hence, moving from a closed to an open economy, the distortion term is always negative.*

[12] In this case, the elasticities are given by $\gamma_\lambda = \frac{\sigma-1}{\sigma}(\theta - \sigma + 1)$ and $\gamma_s = \frac{\sigma-1}{\sigma}(\theta - \sigma)$, and thus $\gamma_s < \gamma_\lambda$.

PROOF: Appendix B.3.

In the appendix, we prove that if $\sigma_\tau \geq \frac{\sigma-1}{\sigma}\rho\sigma_\varphi$, the likelihood ratio order dictates that the cumulative distribution of labor share stochastically dominates the cumulative distribution of sales share. This implies that among higher-profit firms, the cumulative labor-share distribution has more mass than the cumulative sales-share distribution. Thus, as the economy opens up to trade and higher profit firms begin exporting, the share of labor used to produce exports exceeds the export share, resulting in $S \leq \lambda$. In addition, $\gamma_s \leq \gamma_\lambda$ holds, indicating that the domestic market also selects the relatively higher-profit firms whose share of labor exceeds production.

The condition $\sigma_\tau \geq \frac{\sigma-1}{\sigma}\rho\sigma_\varphi$ holds definitively when the correlation is negative $\rho < 0$ —that is when productive firms are more likely to be subsidized. Hence, exporters are those that are productive and subsidized, ending up with larger labor shares than their sales shares. The fiscal externality term is always negative when the correlation is negative. See Appendix C for numerical results with different correlation ρ.

It should be emphasized that a country's potential loss from trade does not simply come from the deterioration of its terms of trade resulting from export subsidy. To clearly illustrate this point, we have excluded the terms of trade effect and provide a numerical example in Appendix C. In this example, two symmetric countries with identical domestic distortions engage in trade. We show that both countries suffer losses from trade and these losses cannot be attributed to a decline in the terms of trade, as the terms of trade remain constant. Rather, the losses are caused by negative selection and worsen of misallocation of resources.

3 Quantitative Analysis

This section presents a quantitative analysis of trade liberalization in the presence of domestic distortions, estimating the model based on data from China and the United States.

We need a panel data with information on firms' market output and input usage at different levels of trade costs to measure firm entry and labor responses, as well as the domestic trade elasticity and labor elasticity. But this information is not available, added to the fact that the underlying distortions and productivity significantly changed over time. Thus, we opt to use our model to estimate and quantify trade gains with firm-level distortions.

The main purpose is to use China as an example to demonstrate the large quantitative and qualitative differences that may emerge under a model with distortions, compared to the standard model without distortions. A substantial negative distortions effect can offset much of the gains to trade commonly understood.

To this end, we extend the benchmark model to incorporate additional heterogeneity in distortions, allowing firms to face different distortions in the foreign market. Our analysis involves using Chinese firm-level data to match a broad range of moments with the extended model. Through the welfare decomposition, we show that there is a significant negative distortion term that arises when China opens its economy to trade. Lastly, we examine the period from 1998 to 2005, decompose China's growth, and assess the contribution of standard trade.

3.1 Extended model

The benchmark model in Section 1 is expanded upon to include two additional wedges, an export wedge τ_{ex} on foreign sales, and a wedge on the fixed cost of exporting τ_{fx}. These two wedges allow firms to face different distortions in the foreign market. A firm draws a quadruple $(\varphi, \tau, \tau_{ex}, \tau_{fx})$ from a cumulative distribution $G(\varphi, \tau, \tau_{ex}, \tau_{fx})$. The optimization problem for domestic production is the same as in (3). The exporting problem becomes

$$\max \frac{p_x q_x}{\tau_{ex}} - \frac{w}{\varphi}\tau_x q_x - w\tau_{fx} f_x,$$

where the last term reflects an additional wedge on fixed exporting costs. Firms pay $w\tau_{fx} f_x$, but workers only receive $w f_x$. The firm exports if and only if its productivity is higher than the exporting cutoff $\varphi_x^*(\tau_{ex}, \tau_{fx})$ given by

$$\varphi_x^*(\tau_{ex}, \tau_{fx}) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma-1}\left[\frac{f_x \tau_x^{\sigma-1}}{P_f^{\sigma} Q_f}\right]^{\frac{1}{\sigma-1}} w^{\frac{\sigma}{\sigma-1}} \tau_{fx}^{\frac{1}{\sigma-1}} \tau_{ex}^{\frac{\sigma}{\sigma-1}}.$$

Either a low wedge on sales or a low wedge on the fixed cost of exporting raises the export participation of the firm. A detailed derivation of the extended model is provided in Appendix D.

Proposition 3. *The change in welfare associated with an iceberg cost shock is*

$$d\ln W = \underbrace{\frac{1}{\gamma_\lambda + \sigma - 1}[-d\ln\lambda + d\ln M_e]}_{(ACR/MR)} + \underbrace{\left(\frac{\gamma_\lambda/(\sigma-1)}{\gamma_\lambda + \sigma - 1} + 1\right) d\ln PQ}_{(distortion)}, \tag{21}$$

where the last term captures the deviation from ACR and MR, and

$$\begin{aligned} d\ln PQ &= \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}[-d\ln\lambda + d\ln M_e] \\ &+ \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)\left[(-d\ln\lambda + d\ln S) + d\ln\left(1 + \frac{M_e f_x}{L}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}(\tau_{fx} - 1)\, dG\right)\right]. \end{aligned} \tag{22}$$

Proof: see Appendix E.

As it turns out, the welfare decomposition takes on a similar form as in the benchmark model provided in Proposition 2. It also holds for asymmetric countries and for general distributions of $G(\varphi, \tau, \tau_{ex}, \tau_{fx})$. The additional term reflects the fixed cost wedges. Clearly, when there are no extra heterogeneous wedges on a fixed cost, i.e. $\tau_{fx} = 1$ for all firms, the last term becomes zero, and the main Proposition 2 holds exactly as before, even with different levels of distortions in domestic markets τ, and in foreign markets τ_{ex}. We quantitatively assess below the importance of distortions to output relative to distortions to exporting fixed costs.

3.2 Data and Measurement

The data for Chinese firms comes 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. Information is derived 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.

Our strategy is to use the observed distributions of inputs, value-added, export participation, and export intensity from Chinese firm-level data to estimate the underlying joint distribution of distortions and productivity in conjunction with other parameters in the model.

We do not recover firm-level productivity φ and distortion τ, τ_{ex} directly from the data for two reasons. The first reason is that because of firm selection, one would need to extrapolate unobserved wedges. The observed dispersion and correlation of some measured wedge and productivity pertain to operating firms only. Our model embodies an endogenous selection mechanism. For instance, even if the underlying correlation were negative, the export selection mechanism can induce the observed correlation to *become positive*, for the simple reason that high-taxed firms must be more productive in order to export. The selection mechanism will strengthen any underlying correlation between the two variables. For the same reason, the observed dispersions of the two variables are also the ones after the selection has taken place.

Second, we cannot adopt the customary way to recover a firm's distortion using its value-added per input, given that we do not observe fixed costs and inputs by market. In our model,

$$\frac{pq}{\ell} \propto \tau \left[1 - \frac{f}{\ell(\varphi, \tau)}\right], \quad \frac{p_x q_x}{\ell_x} \propto \tau_{ex} \left[1 - \frac{f_x}{\ell_x(\varphi, \tau_{ex})}\right]. \tag{23}$$

The value-added per input corresponds to what is referred to as TFPR. If there are no wedges, TFPR increases with input ℓ and so a firm's physical productivity, as in Melitz. Without fixed costs, $f = 0$, TFPR measures the firm's wedges, as in HK. In our model with fixed costs, TFPR depends on both productivity and wedge. Therefore, TFPR cannot be used to directly recover the firm's productivity or its wedges. More importantly, even if we set aside the fixed cost issue, we still do not know the inputs used for domestic production and exports. Thus, we cannot directly recover exporters' wedges by markets.

3.3 Parameterization and moments

We assume that the joint distribution G in the home country follows a multivariate log-normal distribution with zero mean μ and a variance-covariance matrix Σ, which is characterized by four standard deviations $(\sigma_\varphi, \sigma_\tau, \sigma_{ex}, \sigma_{fx})$ and six correlations $(\rho_{\varphi,\tau}, \rho_{\varphi,\tau_{ex}}, \rho_{\varphi,\tau_{fx}}, \rho_{\tau,\tau_{ex}}, \rho_{\tau,\tau_{fx}}, \rho_{\tau_{ex},\tau_{fx}})$.

We set the elasticity of substitution between varieties σ to be 3 as in HK. This value is consistent with the estimates from plant-level US manufacturing data in Bernard, Eaton, Jensen, and Kortum (2003). The Home labor L and the entry cost f_e are normalized to 1. We choose foreign labor L_f to be 0.2 to match the relative labor force of the US to China. Given that Foreign affects Home only though aggregate variables, we can assume that Foreign is without distortions while taking the fixed costs f_e, f, and f_x, iceberg cost τ_x, and the dispersion of productivity σ_φ to be the same as those in Home. Then we estimate the mean of foreign productivity $\mu_{f\varphi}$ to match the relative GDP of the United States to China.

Table 1: Parametrization and Moments

Panel A: Parameters		Panel B: Targeted Moments		
Endogenously chosen	Value		Data	Model
Fixed cost of producing f	0.07	Fraction of firms producing	0.85	0.86
Fixed cost of export f_x	0.09	Fraction of firms exporting	0.30	0.30
Iceberg trade cost τ_x	2.85	Import share	0.23	0.23
Mean foreign prod $\mu_{f\varphi}$	2.47	Relative GDP of U.S. to China	1.79	1.79
Std. productivity σ_φ	1.36	Std. TFPQ	1.32	1.32
Std. distortion on home sales σ_τ	1.13	Std. TFPR	0.94	0.95
Std. distortion on export sales, exporters $\sigma_{\tau_{ex}}$	1.01	Std. TFPR, exporters	0.88	0.87
Corr(prod., domestic distortion) $\rho_{\varphi,\tau}$	0.90	Corr (TFPR, TFPQ)	0.91	0.92
Corr(prod., foreign sale distortion) $\rho_{\varphi,\tau_{ex}}$	0.62	Corr (TFPR, TFPQ), exporters	0.90	0.89
Corr(τ, τ_{ex}) $\rho_{\tau,\tau_{ex}}$	0.64	Std. export intensity	0.38	0.33
Std. distortion on export fixed cost $\sigma_{\tau_{fx}}$	0.62	Corr (ex. participation, TFPQ)	0.06	0.06
Corr(φ, τ_{fx}) $\rho_{\varphi,\tau_{fx}}$	0.30	Corr (ex. participation, TFPR)	−0.03	−0.03
Corr(τ, τ_{fx}) $\rho_{\tau,\tau_{fx}}$	−0.10	Corr (ex. intensity, TFPQ)	0.01	−0.01
Corr(τ_{ex}, τ_{fx}) $\rho_{\tau_{ex},\tau_{fx}}$	0.01	Corr (ex. intensity, TFPR)	−0.04	−0.03

Note: Data moments are for the 2005 Chinese National Bureau of Statistics. TFPR and TFPQ are logged. Corr denotes correlation, Std for standard deviation, ex. for export, ex.intensity for export intensity, ex.participation for export participation.

The remaining 14 parameters, including $\{f, f_x, \tau_x, \mu_{f\varphi}\}$, the four standard deviations, and the six correlations, are estimated jointly to match 14 model moments with their data counterparts. The key moments used to estimate productivity and distortions are the joint distribution of firms' value-added and inputs. More precisely, they are used to construct firms' measured revenue-based total factor productivity (TFPR) and quantity-based total factor productivity (TFPQ) in our model[13] and to match them with corresponding moments in the data. We use total inputs instead of variable inputs when constructing TFPR and TFPQ both in the data and in the model. Thus, TFPQ and TFPR as discussed above, do not correspond to φ or τ. However, it is roughly the case for operating firms if f or f_x are relatively small, as shown in equation (23).[14]

The composite inputs with capital and labor taken are $k_{ji}^{\alpha_j} \ell_{ji}^{1-\alpha_j}$ for firm i in the industry j with industry labor share α_j.[15] Following HK, labor shares are not computed from Chinese data due to the prevalence of distortions. These industry labor shares come from the U.S. NBER productivity database, which is based on the Census and the Annual Survey of Manufactures (ASM). Different from HK, we take a firm's total employment to measure ℓ_{ji} rather than the firm's wage bill. We define the capital stock as the book value of fixed capital net of depreciation. TFPR, the value added over total composite inputs, for firm i in industry j, and TFPQ—related to physical productivity—are measured by $TFPR_{ji} = p_{ji}q_{ji}/(k_{ji}^{\alpha_j}\ell_{ji}^{1-\alpha_j})$ and $TFPQ_{ji} \propto (p_{ji}q_{ji})^{\frac{\sigma}{\sigma-1}}/(k_{ji}^{\alpha_j}\ell_{ji}^{1-\alpha_j})$. Both TFPR and TFPQ are measured with their deviations from the industry mean. We find large dispersions in TFPR in China, similar to the levels in HK for the years from 1998 to 2007. Measured TFPR dispersions have come down over time, between 1998 and 2007, as evident in Table A-5.

Table 1 reports the estimated parameters and the moments in the data and model. The moments we choose are the ones that are most relevant to firm productivity and distortion, and firm selection in the open economy. These include the moments of the joint distributions of TFPR and TFPQ across both non-exporters and exporters, the extensive and intensive margin of producing and exporting, and their correlations with the firms' TFPR and TFPQ. Clearly, every parameter matters for the general equilibrium and affects all the moments. However, there is by and large a clear correspondence between certain parameters and moments.

[13] In our model, TFPR is the value-added over total inputs which include both inputs for production and fixed costs, i.e. $TFPR = pq/\ell$. TFPQ is output per input, i.e. $TFPQ = q/\ell$, which also equals $(P^{\sigma}Q)^{\frac{1}{1-\sigma}}(pq)^{\frac{\sigma}{\sigma-1}}/\ell$ using the demand function equation (2).

[14] We employ a bootstrap technique, as in Eaton, Kortum, and Kramarz (2011), to calculate standard errors of moments. The resulting errors are found to be very small.

[15] We don't observe variable and fixed costs separately. Following Bernard, Redding, and Schott (2007), we assume fixed costs take the same composite of capital and labor as variable costs.

The parameter most relevant for matching the fraction of surviving firms is the fixed cost f. A lower fixed cost leads to a higher fraction of survivors. The first-year firm survival rate is used to match the share of producing firms. Firm-level data of the sample periods reveals that roughly an average of 85% of entrants survive into the second year. The estimated value of f is low—about 0.07.

The export costs f_x and τ_x determine the export participation and import share in Chinese manufacturing. Export participation is measured as the fraction of firms exporting among the sample firms. The export intensity of each firm is the ratio of the export sales over the sales of the firm. Both are in nominal terms. In addition, we calculate the import share as total exports over total sales across all the firms, given the balanced trade assumption. The sensitivity analysis of the case without balanced trade is explored in Appendix I.2.

Note that the estimated value of the parameter τ_x is 2.85, which suggests that China has a high trade cost in 2005. This value is in line with the findings in Tombe and Zhu (2019), which estimates the export costs from different Chinese regions ranging from 2.6 to 6 in 2002 and a similar range in 2007. Lastly, the estimated mean foreign productivity $\mu_{f\varphi}$ is 2.47, which produces a relative US-China GDP of about 1.79.

The dispersions in productivity and distortions, and their correlations are important for matching the observed joint distribution between TFPR and TFPQ in the data. As we show in equation (23), TFPR increases with both productivity and output wedges. In the model, a firm's TFPQ is given by $q/\ell = \varphi[1 - f/\ell(\varphi, \tau)]$, which implies TFPQ increases with productivity but decreases with output distortions. Hence the standard deviations, σ_φ for productivity, σ_τ for domestic sale distortion, and $\sigma_{\tau_{ex}}$ for foreign sale distortion, shape the standard deviations of TFPQ and TFPR of non-exporters and exporters. The estimation calls for a smaller dispersion of exporting wedge $\sigma_{\tau_{ex}}$ (1.01) than that of domestic wedge σ_τ (1.13), to match the lower dispersion of TFPR among exporters than that among non-exporters. The correlations of productivity and distortions are linked to the correlations of TFPQ and TFPR among exporters and non-exporters. Both $\rho_{\varphi,\tau}$ and $\rho_{\varphi,\tau_{ex}}$ are positive—0.90 and 0.62 respectively.

Under the estimated value of fixed cost f and f_x, τ_x, and foreign productivity, underlying distributions should generate firm selection observed in the data: export participation and intensity, and their correlation with firm TFPR and TFPQ. In the model, the export intensity of a firm is given by $\frac{p_x q_x}{pq + p_x q_x} = \frac{1}{1+(P^\sigma Q/(P_f^\sigma Q_f))(\tau_x \tau_{ex}/\tau)^{\sigma-1}}$, which depends on the iceberg cost τ_x and the relative distortion of selling to the foreign and domestic market, τ_{ex}/τ. The average export intensity is affected by the iceberg cost. The standard deviation of export intensity is affected by $\rho_{\tau,\tau_{ex}}$, the correlation between τ and τ_{ex}, and endogenous selection. When $\rho_{\tau,\tau_{ex}} = 1$, the export intensity is constant across firms. In the data, the standard deviation of export intensity is 0.38, which calls for a correlation of the two wedges of about 0.64. Evidently, the correlations of export intensity with TFPR and TFPQ are also informative about the underlying distributions of productivity and distortions.

Lastly, heterogeneous wedges on fixed exporting costs also matter for the model moments. The standard deviation of the export fixed cost, τ_{fx}, affects export participation and hence the distribution of TFPQ and TFPR for exporters and how they relate to export participation. The correlation between fixed wedges and productivity and output wedges further affect selection. Our estimation shows a positive $\rho_{\varphi,\tau_{fx}}$ such as 0.3, and a negative $\rho_{\tau,\tau_{fx}}$, -0.1. The two exporting wedges, τ_{ex} and τ_{fx}, are almost uncorrelated—about 0.01.

Model fit. Panel B of Table 1 reports the targeted moments in the model and the data. Our model matches well all the empirical targets. First, our model produces the observed fraction of firms producing (0.85) and exporting (0.3), and the import share (0.23). Second, our model successfully replicates the distributions of TFPR and TFPQ, among all firms and across exporters. The overall standard deviation of TFPQ is 1.32 in both the data and the model. The standard deviation of TFPR is 0.94 for all of the firms and 0.88 for exporters in the data, compared to 0.95 and 0.87 in the model. Our model matches the correlation of TFPR and TFPQ for exporters and the correlation across all firms, around 0.9, despite the fact that the underlying correlation $\rho_{\varphi,\tau_{ex}}$ is 0.62, which is much lower than 0.9 for $\rho_{\varphi,\tau}$. The estimated differences in the correlation of the underlying distribution reflect the selection effects.

The distortions significantly impact both the extensive and intensive margins of trade. We proceed to examine trade correlations, i.e., how the export participation and intensity vary with TFPR and TFPQ. The export participation is weakly positively correlated with TFPQ, 0.06, and it is weakly negatively correlated with TFPR, about -0.03, in both the data and the model. With small fixed costs, φ influences more TFPQ, and τ or τ_{ex} influences more TFPR. The signs of these trade correlations show that firms with higher productivity and lower wedge are more likely to become exporters.

Model validation To validate the model, we consider various non-targeted moments, such as TFPR and TFPQ among exporters and non-exporters; correlations between export intensity and exporters' TFPR and TFPQ. These non-targeted moments are successfully replicated by our model, as Table 3 shows.

Furthermore, we assess the model assumption of the log-normal distribution of productivity and wedges. Due to endogenous selection, we cannot extract the underlying distribution directly using non-parametric methods. Nonetheless, we still leverage the model's estimated fixed cost f to back out (φ_i, τ_i) for each non-exporting firm. We then compare this backed-out data distribution with the model's distribution of non-exporters. However, the same cannot be adopted for exporters as labor used for domestic and exporting production is not separately observed.

Specifically, we use our estimated fixed cost f, along with observed value-added pq_i and input ℓ_i, to recover (φ_i, τ_i) for a non-exporting firm i in the following way: $\tau_i = \frac{\sigma-1}{\sigma} \frac{pq_i}{\ell_i - f}$ and $\varphi_i = const \times \frac{(pq_i)^{\frac{\sigma}{\sigma-1}}}{\ell_i - f}$, where the constant $const$ is the same for non-exporters. To ensure consistency with the data, we normalize firms inputs with total inputs and convert the model f to the data one using $f^{data} = Mf/M_d^{data}$, where M and M_d^{data} are the total numbers of firms in the model and data, respectively. By performing these calculations, we are able to recover $\log \varphi_i$ and $\log \tau_i$ for each firm, which we then demean by industry.

Note that in this procedure, no assumptions are made about the distribution of productivity and wedges in the data. Nonetheless, the comparison between the model and data distributions indicates a close match, as illustrated in Figure A-7 in the appendix. The standard deviation of $\log(\varphi)$ is 1.36 in the data and 1.35 in the model, while the standard deviation of $\log(\tau)$ is 1.01 in the data and 1.03 in the model. Moreover, the correlations between productivity and wedge are also comparable, with a value of 0.92 in the data and

0.93 in the model.

In sum, these estimations can serve to uncover the underlying distributions of productivity and distortions: there is a high level of firm-level distortions, which are highly correlated with firms' productivity. Distortions in the exporting market are relatively less dispersed and less correlated with productivity, but after selection, exporters are still the more subsidized ones.

3.4 Implied Gains from Trade

This section explores the gains from trade in our benchmark and compares them to the case where there are no distortions. A decomposition of welfare in the extended model given in Proposition 3 can help us understand the source of the gains.

Table 2 reports the Home country's gain from trade and welfare decompositions. In the benchmark case, China's opening up is associated with a welfare loss of 3.68% according to our model. By contrast, the ACR/MR formula, $\frac{1}{\gamma_\lambda+\sigma-1}(-d\ln\lambda + d\ln M_e)$, predicts a welfare gain of about 11%. The loss from trade comes from the large and negative distortion term showing up in China, amounting to -15%.

We can further decompose the distortion term in Proposition 3 as in equation (22) . The negative fiscal externality ($d\ln PQ$) is associated with a large gap in domestic output share $d\ln\lambda$ and input share $d\ln S$. The second term $\left(\frac{\gamma_\lambda+\sigma-1}{\gamma_s+\sigma-1}\right)(d\ln S - d\ln\lambda)$ is about -13%. The first term, which depends on $\gamma_s - \gamma_\lambda$, contributes only -1%, while the terms reflecting the wedges on fixed exporting cost are negligible at 0.03%.

The welfare changes considered entail significant changes in trade costs as the economy moves from an open to a closed economy. However, the welfare formula (21) is more accurate for small variations in trade cost. Therefore, using the formula directly with the partial elasticities from the open equilibrium results in errors. To address this issue, we present two methods for welfare decomposition, a *direct method* and *cumulative method*, as shown in Table 2.

The direct method calculates γ_s and γ_λ using the domestic cutoffs at the open equilibrium, and $d\ln M_e$ computed as the difference in M_e between the open and closed economy, and similarly for $d \ln \lambda$ and $d \ln S$. This method generates an ACR/MR term of 11.1% and a distortion of -15.01%. The sum of the two values is -3.91%, which is about 0.23% lower than the welfare difference calculated directly using the open and closed equilibrium. The direct method is relatively easy to implement. It, however, involves some minor inaccuracies.

The cumulative approach deals with the approximation problem by integrating welfare compositions from a sequence of small changes in iceberg cost. Specifically, we discretize a large number of trade costs between our benchmark $\tau_x^{bench} = 2.85$ and an extremely large iceberg cost that makes the equilibrium identical to the closed equilibrium. We sum over the welfare changes and decomposition terms under any two adjacent τ_x. For each pair of τ_x, we use the γ_λ and γ_S from the lower τ_x.[16] Given the small changes in iceberg cost, the decomposition holds precisely. The resulting sum of ACR/MR term is 11.23%, and the distortion is 14.91%. Both values are close to those in the direct approach, similarly for the decompositions of fiscal externality $d \ln PQ$. The reason is that in the estimated range, the change of elasticities is relatively small, while the distortion terms are very large.

The foreign country benefits from a trade gain of approximately 10%, and the ACR formula provides a close approximation of this gain. This is due to the absence of any domestic distortions faced by the foreign country. When the home country has no distortions, the foreign country's trade gain is also approximately 10%. See Appendix I.1 for details.

3.5 Role of Distortions

This section examines the effects of distortions and key moments on the gains from trade. We begin with comparative statics on distortions and then evaluate the impact of chosen moments on welfare by conducting alternative estimations that match only some of the moments. Lastly, we explore other sources of heterogeneity that distinguish exporters from non-exporters beyond export wedges.

[16] The results are the same if we use γ_λ and γ_S from the higher trade cost given the small distance between the two adjacent τ_x.

Table 2: Welfare Implications

Gain from trade	-3.68	
Source of elasticities	Direct Method (From open eqm)	Cumulated Method $\left(\sum_i^{N_\tau} \Delta W_i\right)$
Welfare decomposition		
ACR/MR term (1)	11.10	11.23
Distortions (2)	-15.01	-14.91
Overall, (1)+(2)	-3.91	-3.68
Fiscal externality ($d \ln PQ$) decomposition	-14.53	-14.53
Term 1 (related to $\gamma_s - \gamma_\lambda$)	-1.24	-1.05
Term 2 (related to $d \ln S - d \ln \lambda$)	-13.65	-13.51
Term 3 (related to τ_{fx})	0.03	0.03

Note: All numbers are in percent. Welfare decomposition is conducted according to Prop 3. The 'Direct Method' calculates the gain from trade as the difference between the welfare of the baseline open economy and that of a closed one. In this case, the welfare decomposition uses the elasticities γ_s and γ_λ from the equilibrium in the open economy. The 'Cumulated Method' discretizes a number of N_τ trade costs that range from the baseline calibrated value of 2.85 to an extremely high value, so that the cumulative welfare gain $\left(\sum_i^{N_\tau} \Delta W_i\right)$ equals the difference between open and closed. In this case, the welfare decomposition involves summing the decomposition terms between any two adjacent trade costs. Term 1 in $d \ln PQ$ is given by $\frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}(-d \ln \lambda + d \ln M_e)$. Term 2 in $d \ln PQ$ is given by $\left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)(d \ln S - d \ln \lambda)$. And Term 3 related to fixed exporting cost is given by $\left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right) d \ln \left(1 + \frac{M_e f_x}{L} \int_{\varphi_x^*(\tau_{ex}, \tau_{fx})}^{\infty} (\tau_{fx} - 1)\, dG\right)$.

3.5.1 Comparative Statics

To understand the sources of welfare loss, we consider three comparative statics, no τ_{fx}, no output wedges, and no wedges at all. In all these three analyses, all the other parameters remain the same as in the benchmark

The third column of Table 3 shuts down the distortions on fixed exporting cost τ_{fx}. The welfare loss after trade becomes smaller, 3.33% relative to the benchmark of 3.68%. However, the country still suffers a loss from trade, and the distortion term is still highly negative, about -15%. Hence, the τ_{fx} wedge affects little the overall welfare and fiscal externality. Table 3 also reports the key moments under this case. The fixed cost wedge mainly affects two moments: the correlation of export participation with TFPQ, rising from 0.06 to 0.17, and the correlation of export intensity with TFPQ, increasing from -0.01 to 0.08. This distortion has little impact on the dispersion of TFPR and TFPQ and their correlations—which is critical for the overall welfare.

The fourth column of Table 3 shuts down the output wedges τ and τ_{ex} but keeps τ_{fx}. Without output wedges, the dispersion of TFPR for both non-exporters (going from bench-

Table 3: Welfare, Distortions, and Moments

	Data	Benchmark	Bench Parameters			Reestimation		
			No τ_{fx}	No output wedge	No wedges	No τ_{fx} $\tau \neq \tau_{ex}$	No τ_{fx} $\tau = \tau_{ex}$	Hetero-trade-costs
Home welfare gains (%)								
Overall		−3.68	−3.33	2.58	2.60	−0.48	0.85	5.54
ACR/MR term		11.10	11.22	2.58	2.60	11.52	7.73	11.62
Distortion term		−15.01	−14.77	0.00	0.00	−12.19	−6.97	−6.21
Key Moments								
Std. TFPQ	1.32	1.32	1.30	0.84	0.84	1.32	1.33	1.36
Std. TFPR	0.94	0.95	0.95	0.11	0.11	0.95	0.94	0.84
Corr (TFPR, TFPQ)	0.91	0.92	0.92	0.88	0.87	0.91	0.91	0.93
Std. export intensity	0.38	0.33	0.31	0	0	0.33	0	0.28
Among Exporters								
Std. TFPQ.	1.25	1.34	1.26	0.63	0.55	1.26	1.33	1.26
Std. TFPR.	0.88	0.87	0.89	0.03	0.02	0.87	0.91	0.69
Corr (TFPR, TFPQ)	0.90	0.89	0.91	0.81	0.88	0.90	0.97	0.87
Among Non-Exporters								
Std. TFPQ.	1.34	1.31	1.30	0.55	0.52	1.30	1.33	1.40
Std. TFPR	0.96	0.98	0.97	0.11	0.11	0.97	0.90	0.89
Corr. (TFPR, TFPQ)	0.93	0.93	0.93	0.96	0.97	0.93	0.98	0.96
Trade Correlations								
Corr (part., TFPQ)	0.06	0.06	0.17	0.74	0.78	0.23	0.06	0.10
Corr (part., TFPR)	−0.03	−0.03	0.01	0.48	0.51	0.10	−0.31	−0.04
Corr (intensity, TFPQ)	0.01	−0.01	0.08	0.74	0.78	0.09	0.06	0.02
Corr (intensity., TFPR)	−0.04	−0.03	0.003	0.50	0.51	0.05	−0.31	−0.05

Note: TFPR and TFPQ are logged. Corr denotes correlation, Std for standard deviation, 'intensity' for export intensity, 'part.' for export participation. The case 'No τ_{fx}' shuts down τ_{fx}, $\tau_{fx} = 1$. The case 'No output wedges' shut down both τ and τ_{ex}, $\tau = \tau_{ex} = 1$. The case 'No wedges' shuts down all distortions $(\tau, \tau_{ex}, \tau_{fx})$. The other parameters in these three cases are the same as the benchmark. For 'Reestimation (No τ_{fx}, $\tau \neq \tau_{ex}$)', we estimate the model with no τ_{fx} but allowing for differential τ_{ex} and τ. In this case, we do not target the four trade correlations. For 'Reestimation (No τ_{fx}, $\tau = \tau_{ex}$)', we estimate the model with no τ_{fx} and $\tau = \tau_{ex}$. In this case, we do not target within-group distributions of TFPR and TFPQ and the four trade correlations. For 'Reestimation hetero-trade-costs', we estimate a case without export wedges but with the heterogeneous iceberg and fixed exporting costs. The parameters and other moments for the cases under 'Reestimation' are reported in Table A-2 of the appendix. ACR and Distortion in the welfare decomposition are constructed according to (Eq.21).

mark 0.98 to 0.11) and exporters (from benchmark 0.87 to 0.03) change dramatically; the overall welfare gain from trade becomes positive, 2.58%, close to the efficient case gains of 2.60%. The distortion term is close to zero. Export participation is driven by productivity and τ_{fx}. The export participation and intensities are largely positively correlated with TFPR and TFPQ, which are inconsistent with the data.

The fifth column of Table 3 shows the results under no distortions, with heterogeneity coming only from productivity. The gain is the highest in this case. There is still some dispersion in TFPR because of the presence of fixed cost, as discussed in Section 3.2. But the productivity dispersion generates only about one-tenth of TFPR dispersion in the benchmark, given the low fixed cost.

In sum, our welfare calculations deviate substantially from ACR, as a result of the distortion term. Between the two types of distortions, the output wedge is by far the more important in generating these results. Distortions on the fixed cost of exporting help generate the co-movement in exports, TFPR, and TFPQ, but contributes little to fiscal externality and the overall welfare.

3.5.2 Alternative Estimations

To understand the role of the chosen moments for the welfare implications, we conduct two alternative estimations in Table 3. Specifically, we shut down some moments related to TFPR and TFPQ and their attendant distortions while reestimating all the other parameters. The estimated parameters and comprehensive moments are presented in Table A-2 in the appendix.

In the first case, we target the same set of moments as in the benchmark except for the trade correlations, i.e. the co-movements of export intensity and participation with TFPR and TFPQ. Given fewer moments than the benchmark, we shut down τ_{fx} but allow for differential output wedges on domestic and foreign sales, $\tau \neq \tau_{ex}$. The model successfully produces the moments of average extensive production and trade margins, the standard deviations of TFPR, TFPQ, and their correlations among exporters and non-exporters.

The export participation is too correlated with TFPQ, and it increases from 0.06 in the benchmark to 0.23. Its correlation with TFPR also increases from -0.03 to 0.1. The correlations of export intensity with TFPQ and TFPR follow a similar pattern. The overall welfare change is higher, −0.48% compared to −3.68% in the benchmark. However, the distortion term is still large and negative, about −12%, comparable to the benchmark value −15%.

In the second case, we further shut down the heterogeneity between the output distortions on domestic and foreign sales. In this case, we give up generating the group-specific distributions of TFPR and TFPQ and consider only the overall dispersions of TFPR, TFPQ, and their correlations, which the estimation successfully produces. Even though the correlation of TFPR and TFPQ across all firms matches the data, the model overestimates these correlations for both exporters and non-exporters. It also misses the trade correlations with TFPR and TFPQ.

With fewer distortions, the welfare gain from trade increases to 0.85%, while the negative impact of distortion is less severe, at around −7%. Although the ACR gain remains around 11% in this analysis, reflecting the same import share as the benchmark model, the gain from entry is considerably more negative following trade. This is due to a higher calibrated fixed cost of exporting, f_x, as shown in Table A-2 in the appendix. The more negative MR term drives down the overall ACR/MR term to 7.7%, which is smaller than the benchmark number.

3.5.3 Other Source of Heterogeneity

In our baseline model, we incorporate distortions of the Hsieh-Klenow type to account for the observed TFPR and examine the resulting fiscal externality. Specifically, we use heterogeneous export wedges to help the model generate the exporters' TFPR dispersion and the correlation of trade with TFPR. This raises the question of whether introducing other forms of heterogeneity in the export market could enable the model to capture the data TFPR pattern while yielding different welfare gains and fiscal externalities.

To address this question, we consider an alternative model named *hetero-trade-costs* model, which does not involve export wedges but instead includes firm-specific iceberg and fixed costs related to exporting.[17] Unlike export wedges, these differential costs op-

[17] In the data, we do not observe the amount of labor used for exports and domestic sales separately, we cannot allow for both heterogeneous trade costs and heterogeneous export taxes and separately identify them.

erate akin to differential productivities but do not cause resource misallocation. Hence, production for export faces no distortions in this model. Although the hetero-trade-costs model appears to be as rich as the benchmark model at first glance, we find that this model does not match the data as well as the benchmark. see Appendix G and Table A-2 for details.

The challenges lie in matching the large variability in TFPR among exporters and the negative correlation between TFPR and trade in the data. In this model, one way to generate a large dispersion of TFPR is to increase the standard deviation of heterogeneous trade costs. However, this leads to a positive correlation between TFPR and export, which contradicts the data. This happens because when trade costs are low, firms' exporting productivity increases, leading to higher levels of TFPR and export participation and intensity.

Another way is to use a large dispersion in domestic wedges, along with a strong positive correlation between domestic wedges and trade costs. This approach can generate a highly dispersed TFPR and a negative correlation between TFPR (when domestic wedge τ is low) and export participation (when export costs are low). However, this approach has two limitations: a very positively correlated export intensity and TFPR and an implication that heavily subsidized domestic firms are more technologically advanced in exporting, which seems ad-hoc. Instead, the equilibrium in our benchmark model features highly subsidized firms exporting more because they receive more subsidies, not because of better technology. The wedge perspective aligns better with empirical evidence in China.

Compared to our benchmark model, the hetero-trade-costs model performs less satisfactorily in matching the data moments, as shown in the last column of Table 3. For instance, the standard deviation of TFPR is 0.69 for exporters and 0.89 for non-exporters, which are both lower than the corresponding values in the data of 0.88 and 0.96, respectively. To measure the distance of the model from the data, we use a moment error function with a weighting matrix as the identity matrix. This is equivalent to a sum of squared errors. The resulting distance in the hetero-trade-costs model is 0.01, about five times higher than the benchmark distance to the data, 0.002.

Table 3 reports the gains from trade and welfare decompositions in the hetero-trade-costs model. The gain from trade is 5.54%, the ACR/MR term is approximately 11%, and the distortion term is -6.21%. Note that the ACR/MR term is similar to the benchmark since both models match the trade flows and generate similar partial elasticities.

In contrast to the benchmark, the hetero-trade-costs model shows a distortion term that is less negative and with smaller distortions. This is due to the absence of distortion in production within the exporting market. However, it is important to note that the fiscal externality remains negative because the overall domestic production is taxed. The reason for that is that estimated productivities are more dispersed than wedges and highly positively correlated with wedges, as shown in Table A-2 in the appendix. As a result, domestic productions are taxed, and exporting productions are relatively subsidized. Opening up the market still generates a negative fiscal externality.

In summary, our benchmark model abstracts from other technology differences that could cause variations in TFPRs between exporters and non-exporters. The hetero-trade-costs model exemplifies a case, where selecting to export is driven by the heterogeneous variable and fixed trade costs. Nonetheless, the model needs other types of wedges to generate the observed TFPR in exporters and trade correlations with TFPR. As a result, the model still generates a negative fiscal externality and smaller welfare gains compared to ACR.

It is also possible that exporters use technologies with different labor intensities compared to non-exporters. However, like the misallocation literature, we face the challenge of distinguishing between labor intensity and distortions. To address this issue in our empirical analysis, we adopt the approach of Hsieh and Klenow (2009) and assume that the labor intensity of the US 4-digit industry is undistorted. By subtracting the 4-digit industry mean, we ensure that the observed differences in TFPR between exporters and non-exporters are not influenced by variations in labor intensity, at least across the 4-digit industries. Nonetheless, it is possible that exporters possess different technologies within the 4-digit sectors, which we are unable to distinguish.

The processing trade is another possibility that Chinese exporters end up with different TFPRs from non-exporters. To identify which firms engage in this type of trade, the standard procedure is to combine data from the Chinese Manufacturing Survey with custom data. However, this approach has two limitations. First, in 2005, only 60% of the exporters were matched with the custom data, resulting in a loss of 40% of exporter information. Second, among the matched exporters, approximately 73% of firms engage in both processing and ordinary trade, making it difficult to distinguish how these firms allocate their inputs between the two types of trade. As a result, it is currently difficult to calculate the TFPR for different activities for these firms. Nonetheless, this issue presents an interesting research opportunity for future studies, particularly when more comprehensive data become available.

3.6 Decomposing China's Growth from 1998-2005

The rapid growth in China over the last four decades has been one of the most remarkable phenomena the world has witnessed in recent history. Between 1998 and 2005, its real GDP increased by 57%. Accompanying this development was a combination of domestic reforms and opening up programs—policies that fostered trade and FDI inflows. As a result, both trade and technological progress increased over time, while domestic distortions concurrently fell. A natural question is how much of the growth is attributed to trade over this period. Other competing factors include technological improvement, factor accumulation, and domestic reforms—that is, the allocative gains associated with a reduction in distortions.

In what follows, we perform a quantitative analysis to answer this question. Specifically, we reestimate the model parameters for the year 1998 and compare the implied GDP in the benchmark year, 2005. Overall, our results attribute the majority of China's GDP growth to technological improvement, capital accumulation, and mitigation of distortions. With the only reduction in iceberg trade cost, GDP could only increase by 6% instead of 57%.

Table 4 reports data moments for both 1998 and 2005. We use 1998 as the starting year since it is the first year in which firm-level data is available, and 1998 is also three years before China joined the WTO. Compared to the year 2005, trade intensity was lower in 1998, both in terms of the fraction of exporting firms, and also the export intensity of these firms. The overall dispersion of TFPR is about 20% higher in 1998 compared to 2005. The trade correlations with TFPR or TFPQ are more positive in 1998 than in 2005.

The parameter values and model moments for both 1998 and 2005 are presented in Table

4. The observed data moments are successfully replicated by our model in both years. In 1998, the estimations indicate a higher trade cost τ_x and higher dispersion of distortion σ_τ and $\sigma_{\tau_{ex}}$, which are approximately 34%, 19%, and 9% higher than their levels in 2005. Furthermore, productivity is more dispersed in 1998 compared to 2005, with a standard deviation of 1.59 in 1998 and 1.36 in 2005. The standard deviation of τ_{fx} is smaller in 1998, but our analysis from the previous section suggests that this change has little impact on welfare. The correlations of productivity with distortions in 1998 are similar to those in 2005, given the similar correlation of TFPR and TFPQ in these two years. Home mean productivity in 2005 is approximately 75% higher than that in 1998, reflecting improvements in technology and factor accumulation over time.

Table 4: China Growth Analysis

Panel A: Parameters			Panel B: Targeted Moments				
	1998	2005		1998		2005 (Bench)	
				Data	Model	Data	Model
Fixed cost f	0.03	0.07	Fraction producing	0.85	0.85	0.85	0.86
Fixed export cost f_x	0.05	0.09	Fraction exporting	0.25	0.25	0.30	0.30
Iceberg cost τ_x	3.83	2.85	Import share	0.16	0.16	0.23	0.23
Foreign prod. $\mu_{f\varphi}$	1.08	2.47	U.S. GDP to China	2.60	2.60	1.79	1.79
Std prod. σ_φ	1.59	1.36	Std. TFPQ	1.55	1.53	1.32	1.32
Std home dist. σ_τ	1.34	1.13	Std. TFPR	1.12	1.13	0.94	0.95
Std export dist. $\sigma_{\tau_{ex}}$	1.11	1.01	Std. TFPR, exporter	1.01	1.02	0.88	0.87
$\rho_{\varphi,\tau}$	0.89	0.90	Corr (TFPR, TFPQ)	0.93	0.92	0.91	0.92
$\rho_{\varphi,\tau_{ex}}$	0.68	0.62	Corr (TFPR, TFPQ), ex	0.92	0.92	0.90	0.89
$\rho_{\tau,\tau_{ex}}$	0.64	0.64	Std. export intensity	0.38	0.35	0.38	0.33
Std. export cost $\sigma_{\tau_{fx}}$	0.56	0.62	Corr (ex-part., TFPQ)	0.08	0.09	0.06	0.06
$\rho_{\varphi,\tau_{fx}}$	0.28	0.30	Corr (ex-part., TFPR)	−0.01	0.01	−0.03	−0.03
$\rho_{\tau,\tau_{fx}}$	0.10	−0.10	Corr (ex-int., TFPQ)	0.04	0.01	0.01	−0.01
$\rho_{\tau_{ex},\tau_{fx}}$	0.02	0.01	Corr (ex-int., TFPR)	0.00	0.00	−0.04	−0.03
Home prod. μ_φ	0.57	1.00	log GDP relative to 2005	−0.57	−0.57		

Note: Data moments are constructed using Chinese National Bureau of Statistics. TFPR and TFPQ are logged. Corr denotes correlation, Std for standard deviation, ex for export, ex-int for export intensity, ex-part for export participation.

We use these estimates to run counterfactual experiments in order to decompose China's growth between 1998 and 2005. The factors considered include technological progress (and capital accumulation), the reduction of trade costs, domestic distortion and productivities. In each experiment, the parameters for the year 1998 remain fixed, while each set of the following parameters—mean productivity μ_φ, trade cost τ_x, or the joint distribution of productivity and distortions—are allowed to vary to its 2005 level.

Table 5 indicates that an increase in technology and inputs alone would result in a 55% increase in GDP. Reducing trade costs independently would also increase GDP by 6%, and changing the joint distribution of distortion and productivity to that of 2005 would result in a further 5% increase in GDP.[18]

Notably, almost all parameters in 2005 differ from those in 1998, and among these parameters, the dispersions of domestic productivity and distortion, σ_φ and σ_τ, have the most significant impact on welfare change between 1998 and 2005. The GDP in 2005 would experience a 68% increase due to a reduction in σ_τ if the productivity dispersion is fixed, which dominates the contribution from technology and inputs. Conversely, decreasing σ_φ results in a 66% decrease in GDP in 2005. These two effects offset each other, resulting in a modest 5% increase in welfare if we change the 1998 distribution to the 2005 one. This finding aligns with the Oi-Hartman-Abel effect (Oi 1961; Hartman 1972; Abel 1983) that indicates higher welfare when productivity dispersion is greater. When σ_φ is higher, resources are allocated to more productive firms, leading to higher welfare. Other distribution parameters have a very small impact on welfare change between 1998 and 2005. See Table A-3 in Appendix H for details.

It should be noted that despite having more dispersed distortions, the gain from trade in 1998 is still positive. This is because the relative dispersion of wedges to productivity is smaller in 1998. Our Corollary 2 indicates that it is the relative dispersion that matters. As σ_φ increases, selection becomes more based on productivity, and as σ_φ decreases, selection becomes more based on subsidy. Hence, although 1998 was less efficient, the underlying distribution was highly dispersed in productivity, and the negative fiscal externality of opening up was small. However, from 1998 to 2005, productivity dispersion decreased, and the decrease in domestic distortion was greater than the decrease in exporting distortion. Given the distribution in 2005, there were more negative fiscal externalities associated with opening up to trade. Figure A-8 in Appendix H depicts distortion terms when there are reductions in trade costs, under both 1998 and 2005 calibration.

[18]Note that the contributions to GDP increase don't add up to 100% because there are interacting effects on mean productivity, trade cost, and distortion dispersions.

A notable point of comparison is with Tombe and Zhu (2019), which, despite adopting an altogether different approach, also finds small gains to trade. In their model that features migration across regions and sectors in China, international trade contributes to only 7% of productivity growth between 2000 and 2005. In other words, international trade has led to smaller welfare gains as compared to direct reforms that lower migration costs or reductions in internal trade costs.

Of course, a caveat is that trade may also help reduce domestic distortions. If, say, the WTO requires certain kinds of domestic reforms as a pre-condition for entry, then some of the technological improvement and reductions in the level of distortions could be partially induced by opening up policies. We do not consider this here. Also, this quantitative exercise of course also ignores other potential channels of gains to trade, such as the pro-competition effect of trade, or potential transfers of technology (Ramondo and Rodríguez-Clare (2013))–though these effects may still be quantitatively small. The point we make here is that in our benchmark framework, the contribution of trade cost reduction pales in comparison to the contribution of domestic reforms and technological progress in accounting for China's growth experience.

Table 5: Decomposition of China's Growth between 1998-2005

	Change of Real GDP (%)
Benchmark	57
Counterfactual Change from 1998-2005:	
Technology and inputs alone (Increase mean φ)	55
Trade alone (Decrease τ_x)	6
Distribution alone (Same distribution as 2005)	5
Domestic distortion alone (Decrease σ_τ)	68
Domestic productivity alone (Decrease σ_φ)	-66

4 Conclusion

This paper evaluates the impact of trade liberalization when the economy is subject to firm-level distortions. Given its prevalence and importance in developing countries, it is reasonable to ask how trade might affect welfare when these distortions are taken into account. This paper shows theoretically and quantitatively that opening an economy may in fact reduce allocative efficiency and exacerbate the misallocation of resources, by helping firms that are more subsidized (rather than those that are more productive) to expand. The findings in this paper do not disclaim the potentially wide variety of sources and the magnitude of gains to trade beyond what is taken up in the current framework. But it does highlight that these losses could be sizeable and comparable to major sources of welfare gains. We use Chinese manufacturing data in a period of the economy's rapid integration to demonstrate quantitatively that standard calculations for welfare may grossly overestimate the gains.

The paper serves as a first attempt to understand the interactions between trade and idiosyncratic firm-level distortions on a theoretical level. Extensions of the work can examine how distortions interact with other channels of gains to trade, such as innovation. One can also examine a dynamic model and the sequence of trade and domestic reforms. Our work joins the growing body of work and interest in why developing countries' experience with trade liberalization might have been so curiously diverse and uneven. Our work hopefully lends itself as one explanation to such a question.

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Online Appendix to "Misallocation Under Trade Liberalization"

by Yan Bai, Keyu Jin, and Dan Lu

This appendix is organized as follows.

A Model Derivation

Closed Economy Equilibrium. In a closed economy, taking as given the aggregates prices (P, w) and demand Q, the problem of a firm with (φ, τ) implies the optimal price

$$p(\varphi, \tau) = \frac{\sigma}{\sigma - 1} \frac{w\tau}{\varphi} \tag{A.1}$$

and optimal profit $\pi(\varphi,\tau) = [\sigma^{-\sigma}(\sigma-1)^{\sigma-1}P^{\sigma}Qw^{1-\sigma}]\varphi^{\sigma-1}\tau^{-\sigma} - wf$. The cutoff of production is given by $\varphi^*(\tau) = con_v \times P^{-1}(PQ)^{\frac{1}{1-\sigma}}\tau^{\frac{\sigma}{\sigma-1}}$ with the normalization of $w = 1$ and the constant $con_v = \sigma^{\frac{\sigma}{\sigma-1}}(\sigma-1)^{-1}f^{\frac{1}{\sigma-1}}$.

Let $\mu(\varphi,\tau)$ be the distribution of operating firms $\mu(\varphi,\tau) = \frac{g(\varphi,\tau)}{\int\int_{\varphi^*(\tau)}^{\infty} g(\varphi,\tau)d\varphi d\tau} = \frac{g(\varphi,\tau)}{\omega_e}$ if $\varphi \geq \varphi^*(\tau)$; and 0 otherwise. Define M_e and M as a measure of entrants and operative firms, respectively.

An equilibrium is characterized by an aggregate price index, a free entry condition, and a labor market clearing condition. The aggregate price index is the weighted average of the prices (A.1) of the operating firms:

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} M_e \int\int_{\varphi^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau)d\varphi d\tau. \tag{A.2}$$

The free entry condition requires that the present value of producing equals the entry cost, i.e.,

$$\omega_e E[\pi(\varphi,\tau)] = wf_e, \tag{A.3}$$

where ω_e is the probability of entry, $\omega_e = \int\int_{\varphi^*(\tau)}^{\infty} g(\varphi,\tau)\, d\varphi d\tau$, and the expected profit is given by $E[\pi(\varphi,\tau)] = \int\int_{\varphi^*(\tau)} \pi(\varphi,\tau)\mu(\varphi,\tau)d\varphi d\tau$.

The labor market clearing condition requires

$$L = ME\left[\frac{q}{\varphi} + f\right] + M_e f_e, \tag{A.4}$$

where the average labor demanded by firms is $E\left[\frac{q}{\varphi} + f\right] = \int\int_{\varphi^*(\tau)}^{\infty} \left[\frac{q}{\varphi} + f\right] \mu(\varphi,\tau)\, d\varphi d\tau$. In equilibrium, the number of producers equals the number of entrants multiplying the probability of producing, such that

$$\omega_e M_e = M. \tag{A.5}$$

Noting that $\omega_e E(q/\phi) = (\sigma-1)(\omega_e f + f_e)$, which can be obtained through optimal profit function and the free entry condition, we arrive at

$$M_e = \frac{L}{\sigma\left(f_e + \omega_e f\right)}. \tag{A.6}$$

Open Economy Equilibrium. Optimal prices and cutoff functions are straightforward analogues of the closed economy case. An equilibrium of the open economy consists of seven aggregate conditions: two free entry conditions for Home and Foreign, two aggregate price index for Home and Foreign, two labor market conditions for Home and Foreign, and one balanced-trade condition.

Home's free entry condition is given by

$$\begin{aligned}&\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w^{1-\sigma}\int\int_{\varphi^*(\tau)}^{\infty}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right]g\left(\varphi,\tau\right)d\varphi d\tau - wf\int\int_{\varphi^*(\tau)}^{\infty}g\left(\varphi,\tau\right)d\varphi d\tau\\ &+\left[\frac{P_f Q_f}{\sigma}\left(P_f\frac{\sigma-1}{\sigma}\right)^{\sigma-1}(\tau_x w)^{1-\sigma}\int\int_{\varphi_x^*(\tau)}^{\infty}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right]g\left(\varphi,\tau\right)d\varphi d\tau - wf_x\int\int_{\varphi_x^*(\tau)}^{\infty}g\left(\varphi,\tau\right)d\varphi d\tau\right]\\ &= wf_e. \end{aligned} \tag{A.7}$$

Rewriting this equation

$$\begin{aligned}&w^{1-\sigma}\left[P^{\sigma}Q\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau + P_f^{\sigma}Q_f\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau\right]\\ &= \sigma^{\sigma}(\sigma-1)^{1-\sigma}\left(wf_e + \omega_e wf + \omega_x\omega_e wf_x\right)\end{aligned}$$

where $\omega_e = \int\int_{\varphi^*(\tau)}^{\infty} g\left(\varphi,\tau\right)d\varphi d\tau$ and $\omega_x = \int\int_{\varphi_x^*(\tau)}^{\infty}\mu\left(\varphi,\tau\right)d\varphi d\tau = \frac{\int\int_{\varphi_x^*(\tau)}^{\infty}g(\varphi,\tau)d\varphi d\tau}{\int\int_{\varphi^*(\tau)}^{\infty}g(\varphi,\tau)d\varphi d\tau}$ are the entry probability and the export probability conditional on entry, respectively. Similarly, we can write Foreign's free entry condition

$$\begin{aligned}&\frac{P_f Q_f}{\sigma}\left(P_f\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w_f^{1-\sigma}\int\int_{\varphi_f^*(\tau)}^{\infty}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right]g_f\left(\varphi,\tau\right)d\varphi d\tau - w_f f\int\int_{\varphi_f^*(\tau)}^{\infty}g_f\left(\varphi,\tau\right)d\varphi d\tau\\ &+\left[\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1}(\tau_x w_f)^{1-\sigma}\int\int_{\varphi_{xf}^*(\tau)}^{\infty}\varphi^{\sigma-1}\tau^{-\sigma}g_f\left(\varphi,\tau\right)d\varphi d\tau - w_f f_x\int\int_{\varphi_{xf}^*(\tau)}^{\infty}g_f\left(\varphi,\tau\right)d\varphi d\tau\right]\\ &= w_f f_e. \end{aligned} \tag{A.8}$$

Home and foreign aggregate prices are

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\Big[M\int\int_{\varphi^*(\tau)}^{\infty}(\frac{w\tau}{\varphi})^{1-\sigma}\mu\left(\varphi,\tau\right)d\varphi d\tau + M_f\int\int_{\varphi^*_{xf}(\tau)}^{\infty}(\frac{w_f\tau\tau_x}{\varphi})^{1-\sigma}\mu_f\left(\varphi,\tau\right)d\varphi d\tau\Big], \quad (A.9)$$

$$P_f^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\Big[M_f\int\int_{\varphi^*_f(\tau)}^{\infty}(\frac{w_f\tau}{\varphi})^{1-\sigma}\mu_f\left(\varphi,\tau\right)d\varphi d\tau + M\int\int_{\varphi^*_x(\tau)}^{\infty}(\frac{w\tau\tau_x}{\varphi})^{1-\sigma}\mu\left(\varphi,\tau\right)d\varphi d\tau\Big]. \quad (A.10)$$

Using the free entry and labor market clearing, we have the home and foreign analogue:

$$M_e = \frac{L}{\sigma\left(f_e + \omega_e f + \omega_x\omega_e f_x\right)}. \quad (A.11)$$

Lastly, the balanced trade condition requires

$$P_f^{\sigma}Q_f M\int\int_{\varphi^*_x(\tau)}^{\infty}\left(\frac{w\tau_x\tau}{\varphi}\right)^{1-\sigma}\mu\left(\varphi,\tau\right)d\varphi d\tau = P^{\sigma}QM_f\int\int_{\varphi^*_{xf}(\tau)}^{\infty}\left(\frac{w_f\tau_x\tau}{\varphi}\right)^{1-\sigma}\mu_f\left(\varphi,\tau\right)d\varphi d\tau. \quad (A.12)$$

B Proofs

B.1 Proof for Proposition 2

Proof. To derive the effect of trade cost shock in the economy, let λ be the share of the expenditure on domestic goods as in ACR, using balanced trade condition:

$$\lambda = \frac{\int\int_{\varphi^*(\tau)}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}g(\varphi,\tau)d\varphi d\tau}{\int\int_{\varphi^*(\tau)}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}g(\varphi,\tau)d\varphi d\tau + \frac{P_f^{\sigma}Q_f}{P^{\sigma}Q}\tau_x^{1-\sigma}\int\int_{\varphi^*_x(\tau)}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}g(\varphi,\tau)d\varphi d\tau}. \quad (A.13)$$

We also define S to be the share of variable labor used in producing domestic goods,

$$S = \frac{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau + \frac{P_f^\sigma Q_f}{P^\sigma Q}\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}. \tag{A.14}$$

Note that without distortions, $\lambda = S$.

First, we make use of the following equations: the price index (A.9), and the balance trade condition (A.12), we get

$$P^{1-\sigma} = con_p M_e w^{1-\sigma}\left[\int\int_{\varphi^*(\tau)} (\frac{\varphi}{\tau})^{\sigma-1}g(\varphi,\tau)d\varphi d\tau + \frac{P_f^\sigma Q_f}{P^\sigma Q}\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)} (\frac{\varphi}{\tau})^{\sigma-1}g(\varphi,\tau)d\varphi d\tau\right]. \tag{A.15}$$

Combine with the definition of λ,

$$P^{1-\sigma} = con_p M_e w^{1-\sigma}\frac{\int\int_{\varphi^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau)d\varphi d\tau}{\lambda}.$$

Take log and differentiation of the above equation:

$$(1-\sigma)d\ln P = d\ln M_e + d\ln\left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma}dG(\varphi,\tau)\right] - d\ln\lambda \tag{A.16}$$

Second, use the free entry condition (A.7), the labor market condition, hence the number of firms (A.11) to get

$$\begin{aligned} & w^{1-\sigma}\left[P^\sigma Q\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau + P_f^\sigma Q_f\tau_x^{1-\sigma}\int\int_{\varphi_x^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau\right] \\ & = \sigma^\sigma(\sigma-1)^{1-\sigma}\frac{wL}{\sigma M_e} \end{aligned}$$

Combine with the definition of S,

$$w^{1-\sigma}P^\sigma Q\frac{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}{S} = \sigma^\sigma(\sigma-1)^{1-\sigma}\frac{wL}{\sigma M_e}$$

Take log and differentiation of the above equation:

$$d \ln P^{\sigma} Q + d \ln \left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} dG(\varphi, \tau) \right] - d \ln S = -d \ln M_e \tag{A.17}$$

In sum, we have two equations, and using the definition of γ:

$$(1-\sigma) d \ln P = d \ln M_e - d \ln \lambda - \gamma_\lambda(\hat{\varphi}^*) d \ln \hat{\varphi}^* \tag{A.18}$$

$$d \ln(PQ) = (1-\sigma) d \ln P - d \ln M_e + d \ln S + \gamma_s(\hat{\varphi}^*) d \ln \hat{\varphi}^*. \tag{A.19}$$

Hence

$$d \ln Q = -d \ln P + (-d \ln \lambda + d \ln S) + (\gamma_s(\hat{\varphi}^*) - \gamma_\lambda(\hat{\varphi}^*)) d \ln \hat{\varphi}^*, \tag{A.20}$$

where from the cutoff equation, $\hat{\varphi}^* = con_v \times P^{-1} (PQ)^{\frac{1}{1-\sigma}}$, we have

$$d \ln \hat{\varphi}^* = -d \ln P - \frac{1}{\sigma - 1} d \ln (PQ). \tag{A.21}$$

Solving equations (A.18)-(A.21) gives Proposition 2:

$$d \ln W = \underbrace{\frac{1}{\gamma_\lambda + \sigma - 1} [-d \ln \lambda + d \ln M_e]}_{(ACR/MR)} + \underbrace{\left(\frac{\gamma_\lambda / (\sigma - 1)}{\gamma_\lambda + \sigma - 1} + 1 \right) d \ln PQ}_{(distortions)}, \tag{A.22}$$

where the last term captures the deviation from ACR and MR, and

$$d \ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1} [-d \ln \lambda + d \ln M_e] + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1} \right) (-d \ln \lambda + d \ln S).$$

□

B.2 Proof for Corollary 1

Proof. Under the special case, $\gamma_\lambda = \frac{\sigma-1}{\sigma}(\theta - \sigma + 1)$ and $\gamma_s = \frac{\sigma-1}{\sigma}(\theta - \sigma)$, and the change in welfare becomes $d \ln W = \frac{\sigma}{\sigma-1} [d \ln S - d \ln \lambda]$.

1. Welfare change from a closed to an open economy:

   Because domestic shares are

$$\lambda = \left[\frac{P_f^\sigma Q_f}{P^\sigma Q} \tau_x^{1-\sigma} \left(\frac{\tau_x^{\sigma-1} f_x}{f} \frac{P^\sigma Q}{P_f^\sigma Q_f} \right)^{\frac{\sigma-1-\theta}{\sigma}} + 1 \right]^{-1}$$

$$S = \left[\frac{P_f^\sigma Q_f}{P^\sigma Q} \tau_x^{1-\sigma} \left(\frac{\tau_x^{\sigma-1} f_x}{f} \frac{P^\sigma Q}{P_f^\sigma Q_f} \right)^{\frac{\sigma-\theta}{\sigma}} + 1 \right]^{-1},$$

we know that $\lambda > S$ as long as there is selection to export, i.e., $\frac{\tau_x^{\sigma-1} f_x}{f} \frac{P^\sigma Q}{P_f^\sigma Q_f} > 1$. In an open economy, the input share used to produce for exports exceeds the export share under the special case where reallocation is driven purely by distortions. Thus, $d \ln S$ is more negative than $d \ln \lambda$ when moving from a closed to open economy. Hence, the open economy has an unambiguously lower welfare.

2. The misallocation term is always negative:

   In the welfare expression of Prop 2, the misallocation term becomes

$$d \ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}[-d \ln \lambda] + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1} \right) (-d \ln \lambda + d \ln S),$$

$$= -d \ln \lambda + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1} \right) d \ln S.$$

Because

$$d \ln \lambda = (1 - \lambda) \frac{\theta + 1}{\sigma} d \ln \frac{\tau_x^{\sigma-1} P^\sigma Q}{P_f^\sigma Q_f}$$

$$d \ln S = (1 - S) \frac{\theta}{\sigma} d \ln \frac{\tau_x^{\sigma-1} P^\sigma Q}{P_f^\sigma Q_f},$$

substitute for γ_s, γ_λ, $d \ln \lambda$ and $d \ln S$, the fiscal externality term is

$$-d \ln \lambda + \frac{\theta + 1}{\theta} d \ln S = \frac{(\theta + 1)(\lambda - S)}{\sigma} d \ln \frac{\tau_x^{\sigma-1} P^\sigma Q}{P_f^\sigma Q_f}.$$

$\lambda > S$, hence as long as the trade cost reduction induces larger fraction of exporters, i.e.,

$d\ln\frac{\tau_x^{\sigma-1}P^\sigma Q}{P_f^\sigma Q_f}<0$, the misallocation term is always negative. Q.E.D. □

B.3 Proof for Corollary 2

Proof. Recall the producing cutoff is given by $\varphi^*(\tau)=\hat{\varphi}^*\tau^{\frac{\sigma}{\sigma-1}}$ where $\hat{\varphi}^*=\frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma-1}\left[\frac{wf}{P^\sigma Q}\right]^{\frac{1}{\sigma-1}}w$. Recall $I(\hat{\varphi})$ and $O(\hat{\varphi})$ where I is the cumulative input/labor share in the domestic market, and O is the cumulative sales share in the domestic market.

$$I(\hat{\varphi})=\frac{\int\int_0^{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}{\int\int_0^{\inf}\varphi^{\sigma-1}\tau^{-\sigma}g(\varphi,\tau)d\varphi d\tau}$$

$$O(\hat{\varphi})=\frac{\int\int_0^{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau}{\int\int_0^{\inf}\varphi^{\sigma-1}\tau^{1-\sigma}g(\varphi,\tau)d\varphi d\tau}.$$

Let $i(\hat{\varphi})=I'(\hat{\varphi})$ and $o(\hat{\varphi})=O'(\hat{\varphi})$. The hazard functions γ_s and γ_λ are

$$\gamma_s=-\frac{d\ln(1-I(\hat{\varphi}))}{d\ln\hat{\varphi}}=\frac{i(\hat{\varphi})}{1-I(\hat{\varphi})},$$

$$\gamma_\lambda=-\frac{d\ln(1-O(\hat{\varphi}))}{d\ln\hat{\varphi}}=\frac{o(\hat{\varphi})}{1-O(\hat{\varphi})},$$

When $\frac{i(\hat{\varphi})}{o(\hat{\varphi})}$ increases with $\hat{\varphi}$, i.e. I is likelihood ratio dominates O, then

$$\frac{1-I(\hat{\varphi})}{i(\hat{\varphi})}=\int_{\hat{\varphi}}\frac{i(\hat{\varphi}')}{i(\hat{\varphi})}d\hat{\varphi}'\geq\int_{\hat{\varphi}}\frac{o(\hat{\varphi}')}{o(\hat{\varphi})}d\hat{\varphi}'=\frac{1-O(\hat{\varphi})}{o(\hat{\varphi})},$$

that is, $\gamma_s\leq\gamma_\lambda$.

Let $x=\log\varphi, y=\log\tau$, then $x=\hat{\varphi}+\frac{\sigma}{\sigma-1}y$. Under joint-normal distribution of (x,y), define

$$V(\hat{\varphi})\equiv\frac{i(\hat{\varphi})}{o(\hat{\varphi})}=\frac{\int\exp(\sigma x(\hat{\varphi},y)-\sigma y)g(x(\hat{\varphi},y),y)dy}{\int\exp(\sigma x(\hat{\varphi},y)+(1-\sigma)y)g(x(\hat{\varphi},y),y)dy}$$

where

$$g(x,y)=\exp\left[-\frac{1}{2(1-\rho^2)}\left(\frac{x^2}{\sigma_\varphi^2}+\frac{y^2}{\sigma_\tau^2}-\frac{2\rho xy}{\sigma_\varphi\sigma_\tau}\right)\right].$$

When $\sigma_\tau\geq\frac{\sigma-1}{\sigma}\rho\sigma_\varphi$, $V'(\hat{\varphi})\geq 0$. Then the cumulative labor share distribution stochastically dominates the cumulative sales share distribution according to the likelihood ratio order, and the hazard functions satisfy $\gamma_s \leq \gamma_d$.

Furthermore,

$$\frac{d \ln \frac{1-I(\hat{\varphi})}{1-O(\hat{\varphi})}}{d \ln \hat{\varphi}} = \frac{d \ln(1 - I(\hat{\varphi}))}{d \ln \hat{\varphi}} - \frac{d \ln(1 - O(\hat{\varphi}))}{d \ln \hat{\varphi}} = -\gamma_s + \gamma_d \geq 0$$

then, it follows

$$\frac{1 - I(\hat{\varphi}_x^*)}{1 - I(\hat{\varphi}^*)} \geq \frac{1 - O(\hat{\varphi}_x^*)}{1 - O(\hat{\varphi}^*)}$$

and $S \leq \lambda$.

$$d \ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}[-d \ln \lambda + d \ln M_e] + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)(-d \ln \lambda + d \ln S).$$

Moving from a closed economy to an open economy, as long as $-d \ln \lambda + d \ln M_e > 0$, the misallocation term is always negative. Q.E.D. □

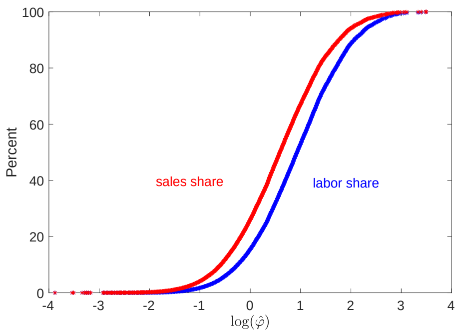
C Numerical Example

To unpack the theoretical results and to provide more intuition for the mechanisms that underpin these results, we next turn to a numerical example of the benchmark model with symmetric countries, i.e., both face domestic distortions. The assumption of symmetry abstracts from terms of trade effect and highlights the role of misallocation in generating loss from trade. Specifically, If Home suffers a loss from trade is not because Home is subsidizing firms' exports and Foreign gains due to a terms of trade effect. This symmetric example emphasizes that loss from trade comes from negative selection and the deterioration of resource allocations.

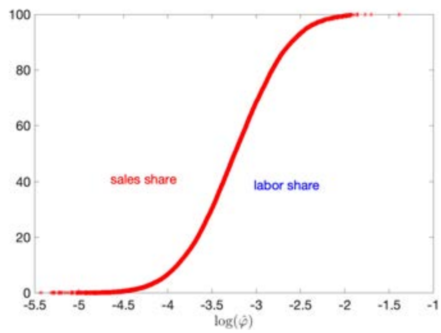
The joint distribution between productivity and distortions is taken to be joint log-normal with standard deviations of $\sigma_\tau = \sigma_\varphi = 0.5$ and correlation of φ and τ of $\rho = 0.8$. The elasticity of substitution σ equals 3, the entry cost and fixed costs of domestic producing are 1, and the fixed cost for exporting f_x is 1.5.

Corollary 2 applies here as the distribution of (φ, τ) and the parameters satisfies its

Figure A-1: Accumulated Labor Share vs Sales Share in a Market



(a) With Distortion



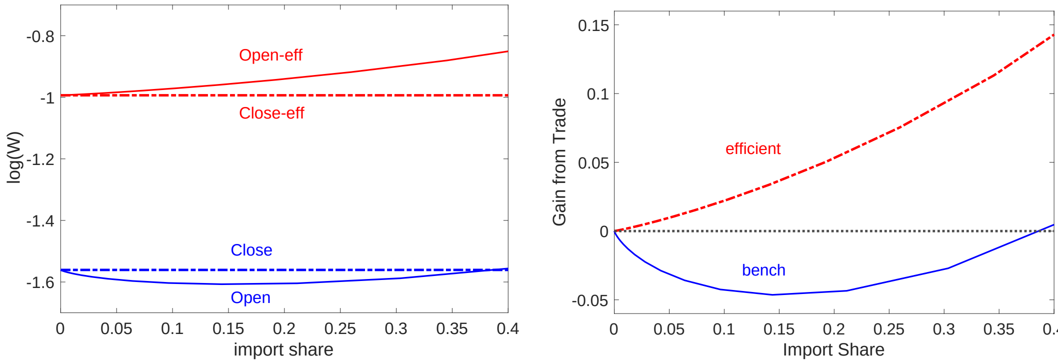
(b) Without Distortion

conditions. We plot the cumulative variable input and sales share under any $\log(\hat{\varphi})$ in panel (a) of Figure A-1. According to Corollary 2, the cumulative variable input share distribution stochastically dominates the cumulative sales share distribution according to the likelihood ratio order, which implies first-order stochastic dominance. In contrast, without distortions with $\tau = 1$, these two distributions are identical, as shown in panel (b) of Figure A-1. When the economy opens to trade, firms that export are those with high profit and also use a large share of labor to produce. Overall, the share of labor used to produce exports would exceed the export share, exporting are more subsidized than domestic production.

The example helps illustrate a few points. First, welfare (Eq. 9) can fall when the economy opens up to trade. Figure A-2 (a) plots the level of welfare against import shares under the alternative scenarios: the efficient case without distortions, the case with distortions, and when the economy is closed or open. Three observations immediately follow: 1) that there is a welfare loss in the case with distortions compared to the case without; 2) opening up to trade leads to welfare gains in the efficient case; however, 3) opening up engenders a welfare *loss* in the presence of distortions. Taking the differences between the open and close economy in either case, with or without distortion, we plot the welfare change after trade in Figure A-2 (b). It is clear that there is welfare loss with distortions.

Second, the numerical example also demonstrates that using import shares to infer welfare changes can gives rise to markedly different results when there are distortions, as in Figure A-3 (a), which decomposes welfare into ACR and a distortion term, compared

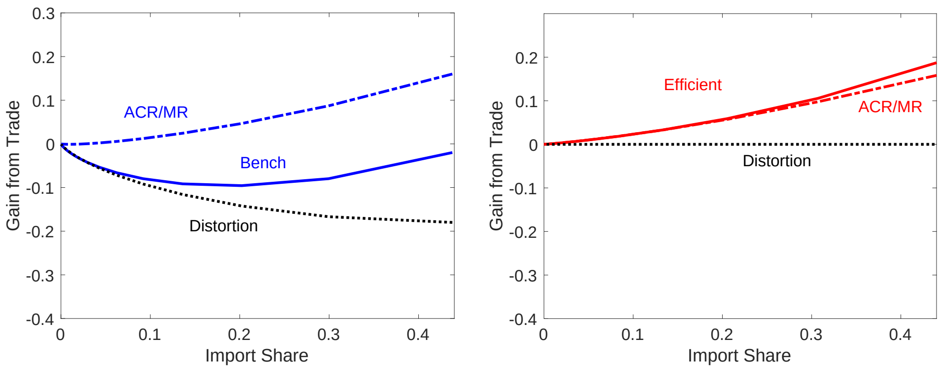
Figure A-2: Welfare and the Change from Trade



(a) Welfare (b) Gain from Trade

against the benchmark. Using ACR under distortions leads to a large departure: welfare *losses* become welfare gains in this case. Thus, using aggregate observables to infer welfare gains as in ACR can thus be very misleading in the presence of distortions, unlike in the efficient case where ACR is a good approximation (Figure A-3 (b)).

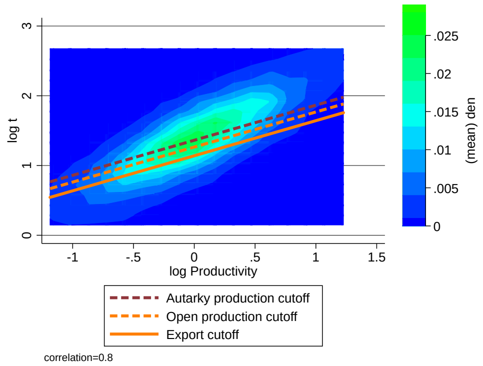
Figure A-3: Welfare Decomposition



(a) With distortion (b) Without distortion

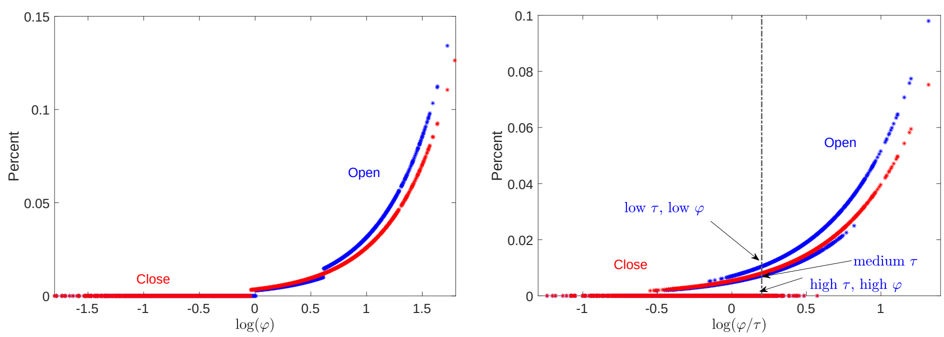
Next, we examine how distortions affect the selection mechanism, in the same numerical example (Figure A-4). The density of firms is shown by a heat map of firms that lie along a positively sloped distortion-productivity line. The productivity cutoff for production and exports is no longer determined solely by productivity, but also by domestic distortion. Only firms below the cutoff line can operate. In this figure, a large mass of highly-productive firms are excluded from servicing the market altogether. As the economy opens up, the cutoff line is shifted further downward. Even if firms have the same level of 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 A-4: Cutoffs



Another way to show the impact on selection is to examine firms' market share. The two panels in Figure A-5 plot the market share of firms, both in the closed and open economy. The left panel is the case without distortions. Without distortion, the marginal cost is the inverse of the productivity φ. 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 A-5: Selection Effects



(a) Without distortion

(b) With distortion

The right panel shows the firm's market share in the case with distortions. Firms may share the same marginal cost τ/φ and face the same potential revenues. However, their after-tax profits may differ, and thus their market share can also differ. Consider the point at which $\log(\varphi/\tau)$ is at 0.2. At this point, a firm with high, medium and low level of productivity faces 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 is a wide range of productivities for which production is excluded.[19] Aggregate welfare effect depends on how trade alters the aggregate domestic labor share and sales share.

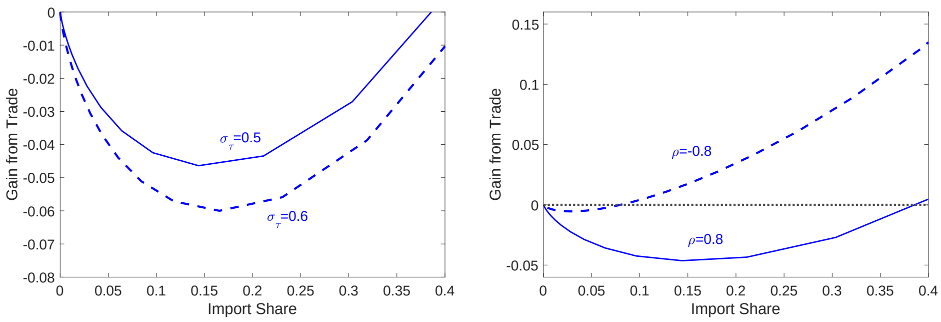
Distribution of Distortions. The distribution of distortions is an important determinant to the gains to trade. There are two key parameters: ρ, the correlation of τ and φ, and σ_τ, the dispersion of τ. Figure A-6 (a) compares the gains from trade under different σ_τ, while the other parameters remain the same as in the benchmark example. The welfare gain (loss) from trade is always larger (smaller) when σ_τ is smaller.

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 for any given productivity, it is always the more subsidized firms that can export, and the highly taxed ones that exit— leading to a possible worsen of misallocation. In fact, as shown in Corollary 2, when the correlation is negative, more productive firms are highly subsidized. Exporters are those more productive and highly subsidized ones, hence their labor share are larger than sales share, and the distortion term is always negative. Overall effects combine the price effect and the negative distortion effect. Figure A-6(a) illustrates this. It compares the gains from trade for $\rho = 0.8$, under our benchmark numerical example, and for $\rho = -0.8$, where productivity and distortion are highly negatively correlated. Under $\rho = -0.8$, the welfare gain (loss) from trade is always larger (smaller) than that in

[19] This is also true if the distortions are input wedge on all the labor a firm uses. Firms face higher input wedge would have a lower profit in a market.

the case of $\rho = 0.8$. But when the import share is small, there are still losses from trade even under a negative correlation.

Figure A-6: Gains/Loss from Trade



(a) Dispersion Matters (b) Correlation Matters

In sum, the size of welfare loss after opening up depends on the correlation of φ and τ and the dispersion of τ. The firm level data helps us identify these parameters. Specifically, in the quantitative section, we will use the firm-level output and use its dispersion and its correlation with firm inputs to estimate the underlying distribution of productivity and distortions.

D Extended model with Heterogeneous Exporting Wedges

In the open economy, an entrant firm draws from a quadruple of productivity φ, wedge of domestic sales τ, wedge of foreign sales τ_{ex}, and wedge of fixed cost in foreign sales τ_{fx}, i.e. $(\varphi, \tau, \tau_{ex}, \tau_{fx})$, from a distribution with pdf $g(\varphi, \tau, \tau_{ex}, \tau_{fx})$ and cdf $G(\varphi, \tau, \tau_{ex}, \tau_{fx})$. Foreign firms draw the quadruple from a pdf g_f and cdf G_f. The foreign country has total labor L_f and endogenous prices of P_f and w_f. Export is subject to an iceberg exporting cost τ_x and f_x, which are the same for all the firms.

A domestic exporting firm solves the following problem

$$\max_{p_x, q_x} \frac{1}{\tau_{ex}} p_x q_x - \frac{w}{\varphi} \tau_x q_x - \tau_{fx} w f_x$$

subject to the foreign demand function $q_x = \frac{p_x^{-\sigma}}{P_f^{-\sigma}} Q_f$. The optimal exporting price is

$$p_x = \frac{\sigma}{\sigma - 1} \frac{w\tau_x\tau_{ex}}{\varphi},$$

and the optimal sales is

$$p_x q_x = \left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} w^{1-\sigma} \tau_x^{1-\sigma} (P_f^{\sigma} Q_f) \left(\frac{\varphi}{\tau_{ex}}\right)^{\sigma-1}.$$

The optimal exporting profit is

$$\pi_x = \sigma^{-\sigma}(\sigma - 1)^{\sigma-1} P_f^{\sigma} Q_f (w\tau_x)^{1-\sigma} \varphi^{\sigma-1} \tau_{ex}^{-\sigma} - \tau_{fx} w f_x.$$

Cutoffs The two cutoff productivities in the home country entering the domestic market, $\varphi^*(\tau)$, and foreign markets, $\varphi_x^*(\tau_{ex}, \tau_{fx})$, are:

$$\varphi^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{wf}{P^{\sigma} Q}\right]^{\frac{1}{\sigma-1}} w\tau^{\frac{\sigma}{\sigma-1}}, \qquad \varphi_x^*(\tau_{ex}, \tau_{fx}) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{\tau_{fx} w f_x \tau_x^{\sigma-1}}{P_f^{\sigma} Q_f}\right]^{\frac{1}{\sigma-1}} w\tau_{ex}^{\frac{\sigma}{\sigma-1}}. \quad \text{(A.23)}$$

Similarly, the two cutoffs for the foreign country are

$$\varphi_f^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{w_f f}{P_f^{\sigma} Q_f}\right]^{\frac{1}{\sigma-1}} w_f \tau^{\frac{\sigma}{\sigma-1}}, \qquad \varphi_{xf}^*(\tau_{ex}, \tau_{fx}) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} \left[\frac{\tau_{fx} w_f f_x \tau_x^{\sigma-1}}{P^{\sigma} Q}\right]^{\frac{1}{\sigma-1}} w_f \tau_{ex}^{\frac{\sigma}{\sigma-1}}. \quad \text{(A.24)}$$

Free Entry Conditions

$$\begin{aligned} &\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w^{1-\sigma} \int_{\varphi^*(\tau)} \left[\varphi^{\sigma-1}\tau^{-\sigma}\right] dG - wf \int_{\varphi^*(\tau)}^{\infty} dG \\ &+ \Big[\frac{P_f Q_f}{\sigma}\left(P_f\frac{\sigma-1}{\sigma}\right)^{\sigma-1} (\tau_x w)^{1-\sigma} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \left[\varphi^{\sigma-1}\tau_{ex}^{-\sigma}\right] dG - w f_x \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty} \tau_{fx} dG\Big] = w f_e, \end{aligned} \quad \text{(A.25)}$$

and similarly for the foreign country:

$$\frac{P_f Q_f}{\sigma}\left(P_f\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w_f^{1-\sigma}\int_{\varphi_f^*(\tau)}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right]dG_f - w_f f\int_{\varphi_f^*(\tau)} dG_f$$
$$+\left[\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1}(\tau_x w_f)^{1-\sigma}\int_{\varphi_{xf}^*(\tau_{ex},\tau_f)}\varphi^{\sigma-1}\tau_{ex}^{-\sigma}dG_f - w_f f_x\int_{\varphi_{xf}^*(\tau_{ex},\tau_{fx})}^{\infty}\tau_{fx}dG_f\right] = w_f f_e \tag{A.26}$$

Measure M **and** M_f Define the fraction of firms operating for the domestic market and the fraction exporting, conditional on producing to be:

$$\omega_e = \int_{\varphi^*(\tau)} dG(\varphi,\tau,\tau_{ex},\tau_{fx}), \qquad \omega_x = \frac{\int_{\varphi_x^*(\tau_{ex},\tau_{fx})} dG\left(\varphi,\tau,\tau_{ex},\tau_{fx}\right)}{\int_{\varphi^*(\tau)} dG\left(\varphi,\tau,\tau_{ex},\tau_{fx}\right)},$$

$$\omega_{ef} = \int_{\varphi_f^*(\tau)} dG_f(\varphi,\tau,\tau_{ex},\tau_{fx}), \qquad \omega_{xf} = \frac{\int_{\varphi_{xf}^*(\tau_{ex},\tau_{fx})} dG_f\left(\varphi,\tau,\tau_{ex},\tau_{fx}\right)}{\int_{\varphi_f^*(\tau)} dG_f\left(\varphi,\tau,\tau_{ex},\tau_{fx}\right)}.$$

Home's free entry condition implies

$$\int_{\varphi^*(\tau)}\left(\frac{1}{\sigma-1}\frac{q}{\varphi}-f\right)dG + \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}\left(\frac{1}{\sigma-1}\tau_x\frac{q_x}{\varphi}-\tau_{fx}f_x\right)dG = f_e,$$

where we replaced the optimal profits π with $\frac{1}{\sigma-1}\frac{wq}{\varphi} - wf$ and π_x with $\frac{1}{\sigma-1}\frac{\tau_x w q_x}{\varphi} - w\tau_{fx}f_x$. Home's labor market clearing condition requires

$$L = M_e\left[\int_{\varphi^*(\tau)}\left(\frac{q}{\varphi}+f\right)dG + \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}\left(\tau_x\frac{q_x}{\varphi}+f_x\right)dG + f_e\right].$$

Using the free-entry condition and the labor market clearing condition, we have

$$M_e = \frac{L}{\sigma\left[f_e + \omega_e f + \omega_x\omega_e f_x + \frac{\sigma-1}{\sigma}f_x\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}(\tau_{fx}-1)dG\right]}, \tag{A.27}$$

and similarly for foreign:

$$M_{ef} = \frac{L_f}{\sigma\left[f_e + \omega_{ef} f + \omega_{xf}\omega_{ef} f_x + \frac{\sigma-1}{\sigma} f_x \int_{\varphi^*_{xf}(\tau_{ex},\tau_{fx})} (\tau_{fx} - 1) dG_f\right]}. \tag{A.28}$$

We can then get $M = \omega_e M_e$ and $M_f = \omega_{ef} M_{ef}$.

Aggregate price level We can write the the aggregate prices of home and foreign as:

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left[M w^{1-\sigma} \frac{\int_{\varphi^*(\tau)} (\frac{\varphi}{\tau})^{\sigma-1} dG}{\int_{\varphi^*(\tau)} dG} + M_f (\tau_x w_f)^{1-\sigma} \frac{\int^{\infty}_{\varphi^*_{xf}(\tau_{ex},\tau_{fx})} (\frac{\varphi}{\tau_{ex}})^{\sigma-1} dG_f}{\int^{\infty}_{\varphi^*_f(\tau)} dG_f}\right] \tag{A.29}$$

$$P_f^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left[M_f w_f^{1-\sigma} \frac{\int_{\varphi^*_f(\tau)} (\frac{\varphi}{\tau})^{\sigma-1} dG_f}{\int_{\varphi^*_f(\tau)} dG_f} + M (\tau_x w)^{1-\sigma} \frac{\int^{\infty}_{\varphi^*_x(\tau_{ex},\tau_{fx})} (\frac{\varphi}{\tau_{ex}})^{\sigma-1} dG}{\int^{\infty}_{\varphi^*(\tau)} dG}\right]. \tag{A.30}$$

Summary of equilibrium conditions The equilibrium consists of $(P, P_f, M, M_f, Q, Q_f, w_f)$ with $w = 1$ as normalization. The equations consist of two free entry conditions (A.25) and (A.26), two labor clearing conditions (A.27) and (A.28), two price indices (A.29) and (A.30), and the balanced trade condition

$$P_f^{\sigma} Q_f M_e \int_{\varphi^*_x(\tau_{ex},\tau_{fx})} \left(\frac{w\tau_x\tau_{ex}}{\varphi}\right)^{1-\sigma} dG = P^{\sigma} Q M_{ef} \int_{\varphi^*_{xf}(\tau_{ex},\tau_{fx})} \left(\frac{w_f\tau_x\tau_{ex}}{\varphi}\right)^{1-\sigma} dG_f. \tag{A.31}$$

Finally, the cutoff functions are given by (A.23) and (A.24).

E Proof of General Welfare Formula in the Extended Model

Proof. 1. Define input S and output λ shares

$$\lambda = \frac{\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG}{\left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{1-\sigma} dG\right] + \frac{P_f^\sigma Q_f}{P^\sigma Q}\tau_x^{1-\sigma}\left[\int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \varphi^{\sigma-1}\tau_{ex}^{1-\sigma} dG\right]}$$

$$S = \frac{\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG}{\left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1}\tau^{-\sigma} dG\right] + \frac{P_f^\sigma Q_f}{P^\sigma Q}\tau_x^{1-\sigma}\left[\int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \varphi^{\sigma-1}\tau_{ex}^{-\sigma} dG\right]}$$

2. Define $\gamma_\lambda(\hat{\varphi})$ and $\gamma_s(\hat{\varphi})$

   $\gamma_\lambda(\hat{\varphi})$—the elasticity of the cumulative sales within the domestic market for firms above a cutoff, and $\gamma_s(\hat{\varphi})$—the elasticity of the cumulative domestic (variable) labor for firms above any cutoff $\hat{\varphi}$, both with respect to the cutoff.

$$\gamma_\lambda(\hat{\varphi}) = -\frac{d\ln\left[\int\int_{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}} (\frac{\varphi}{\tau})^{\sigma-1} dG\right]}{d\ln\hat{\varphi}}, \quad \gamma_s(\hat{\varphi}) = -\frac{d\ln\left[\int\int_{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}} \varphi^{\sigma-1}\tau^{-\sigma} dG\right]}{d\ln\hat{\varphi}}. \tag{A.32}$$

   Note $\int\int_{\hat{\varphi}\tau^{\frac{\sigma}{\sigma-1}}} (\frac{\varphi}{\tau})^{\sigma-1} dG$ is proportional to the cumulative market share (in any given market) of firms above any cutoff $\hat{\varphi}$. Therefore $\gamma_\lambda(\hat{\varphi})$ represents the hazard function for the distribution of log firm sales within a market. Similarly, $\gamma_s(\hat{\varphi})$ represents the hazard function for the distribution of log firm variable labor within a market. $\gamma_\lambda(\hat{\varphi}^*)$ and $\gamma_s(\hat{\varphi}^*)$ are these elasticity evaluated at the domestic production cutoff.

3. Free entry condition

$$\frac{P^\sigma Q}{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w^{1-\sigma}\left[\int_{\varphi^*(\tau)}\left[\varphi^{\sigma-1}\tau^{-\sigma}\right] dG + \frac{P_f^\sigma Q_f}{P^\sigma Q}(\tau_x)^{1-\sigma}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}\left[\varphi^{\sigma-1}\tau_{ex}^{-\sigma}\right] dG\right]$$
$$= wf_x\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty} \tau_{fx} dG + w\omega_e f + wf_e$$

   We can rewrite the equilibrium condition (A.27) of M_e

$$M_e = \frac{L}{\sigma f_e + \omega_e\sigma f + \left[(\sigma-1)\int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \tau_{fx} dG + \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} dG\right] f_x},$$

as the following one

$$\omega_e w f + w f_e = \frac{wL}{\sigma M_e} - \left[\frac{\sigma - 1}{\sigma} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \tau_{fx} dG + \frac{1}{\sigma} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} dG \right] w f_x. \tag{A.33}$$

Replacing $\omega_e w f + w f_e$ in the free-entry condition using (A.33), we have

$$\frac{P^\sigma Q}{\sigma} \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma - 1} w^{1-\sigma} \left[\int_{\varphi^*(\tau)} \left[\varphi^{\sigma-1} \tau^{-\sigma} \right] dG + \frac{P_f^\sigma Q_f}{P^\sigma Q} (\tau_x)^{1-\sigma} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \left[\varphi^{\sigma-1} \tau_{ex}^{-\sigma} \right] dG \right]$$
$$= \frac{1}{\sigma} w f_x \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty} \left(\tau_{fx} - 1 \right) dG + \frac{wL}{\sigma M_e}$$

Using the definition of S and normalizing $w = 1$, we reach the following equation:

$$\frac{P^\sigma Q}{\sigma} \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma - 1} \frac{\left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} dG \right]}{S} = \frac{L}{\sigma M_e} \left[1 + \frac{M_e f_x}{L} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty} \left(\tau_{fx} - 1 \right) dG \right]$$

4. Price index:

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} \left[M_e w^{1-\sigma} \int_{\varphi^*(\tau)} (\frac{\varphi}{\tau})^{\sigma-1} dG + M_{ef} (\tau_x w_f)^{1-\sigma} \int_{\varphi_{xf}^*(\tau_{ex},\tau_{fx})}^{\infty} (\frac{\varphi}{\tau_{ex}})^{\sigma-1} dG_f \right]$$

Replacing the second-term with the following balance trade condition

$$P_f^\sigma Q_f M_e \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \left(\frac{w \tau_x \tau_{ex}}{\varphi} \right)^{1-\sigma} dG = P^\sigma Q M_{ef} \int_{\varphi_{xf}^*(\tau_{ex},\tau_{fx})} \left(\frac{w_f \tau_x \tau_{ex}}{\varphi} \right)^{1-\sigma} dG_f$$

we have

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} M_e \left[\int_{\varphi^*(\tau)} (\frac{\varphi}{\tau})^{\sigma-1} dG + (\tau_x)^{1-\sigma} \frac{P_f^\sigma Q_f}{P^\sigma Q} \int_{\varphi_x^*(\tau_{ex},\tau_{fx})} \left(\frac{\varphi}{\tau_{ex}} \right)^{\sigma-1} dG \right].$$

Using the definition of λ, the above equation becomes

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} M_e \left[\frac{\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{1-\sigma} dG}{\lambda} \right].$$

5. Summary of two equations: from free-entry and pricing index, we have

$$\frac{P^{\sigma}Q}{\sigma}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1}\frac{\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}dG\right]}{S}=\frac{L}{\sigma M_e}\left[1+\frac{M_e f_x}{L}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right)dG\right]$$

$$P^{1-\sigma}=\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}M_e\left[\frac{\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}dG(\varphi,\tau)}{\lambda}\right]$$

Taking log and differentiation of the above two equations:

$$\begin{aligned}d\ln P^{\sigma}Q+d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}dG\right]-d\ln S&\\ =-d\ln M_e+d\ln&\left[1+\frac{M_e f_x}{L}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right)dG\right]\end{aligned}$$

$$(1-\sigma)d\ln P=d\ln M_e+d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}dG\right]-d\ln\lambda$$

The term $d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}dG\right]=-\gamma_s(\hat{\varphi}^*)d\ln\hat{\varphi}^*$ where the last equality uses the cutoff condition: $\varphi^*(\tau)=\frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma-1}[wf]^{\frac{1}{\sigma-1}}w(P^{\sigma}Q)^{\frac{1}{1-\sigma}}\tau^{\frac{\sigma}{\sigma-1}}$. Similarly, in the second equation, $d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}dG\right]$ is such that

$$d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}dG\right]=-\gamma_{\lambda}(\hat{\varphi}^*)d\ln\hat{\varphi}^*=\gamma_{\lambda}\frac{1}{\sigma-1}\left(\sigma d\ln P+d\ln Q\right).$$

6. Plugging γ_s and γ_λ back into the two equations we have

$$\begin{aligned}\sigma d\ln P+d\ln Q+\gamma_s\frac{1}{\sigma-1}\left(\sigma d\ln P+d\ln Q\right)-d\ln S&\\ =-d\ln M_e+d\ln&\left[1+\frac{M_e f_x}{L}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right)dG\right]\end{aligned}\tag{A.34}$$

$$(1-\sigma)d\ln P=d\ln M_e+\gamma_{\lambda}\frac{1}{\sigma-1}\left(\sigma d\ln P+d\ln Q\right)-d\ln\lambda\tag{A.35}$$

7. Finally, solve the above two equations, we have $d \ln W = d \ln Q$ and

$$d \ln W = \underbrace{\frac{1}{\gamma_\lambda + \sigma - 1}[-d \ln \lambda + d \ln M_e]}_{(ACR/MR)} + \underbrace{\left(\frac{\gamma_\lambda/(\sigma-1)}{\gamma_\lambda + \sigma - 1} + 1\right) d \ln PQ}_{(distortions)}, \tag{A.36}$$

where the last term captures the deviation from ACR and MR, and

$$d \ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}[-d \ln \lambda + d \ln M_e]$$
$$+ \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)\left[-d \ln \lambda + d \ln S + d \ln(1 + \frac{M_e f_x}{L} \int_{\varphi_x^*(\tau_{ex}, \tau_{fx})}^{\infty} \left(\tau_{fx} - 1\right) dG)\right]. \tag{A.37}$$

□

F Implied and non-targeted moments

This appendix examines some implied and non-targeted moments. We also compare the distribution of productivity and wedges for non-exporters in both the model and the data.

Table A-1 reports our benchmark model's implied and non-targeted moments. Some of the moments are the implied moments, in the sense that if we match very well the joint distributions of observed TFPQ, TFPR, and trade, we match well these moments, for example, the dispersion of value-added and its correlation with TFPR, TFPQ, and trade. The reason is that when constructing measures like TFPR and TFPQ, we use both value-added and inputs. Specifically, the logarithm of value added is proportional to the log difference between TFPR and TFPQ. By matching the joint distribution of TFPR and TFPQ, we are able to generate the observed standard deviation of value added.

Overall the model tightly matches the standard deviation of value added among all the firms. It generates the observed correlations of value added with TFPR, TFPQ, export intensity, and export participation. On average, exporters have 6% lower TFPR and 17% higher TFPQ than non-exporters in the data. Our model generates the same magnitudes.

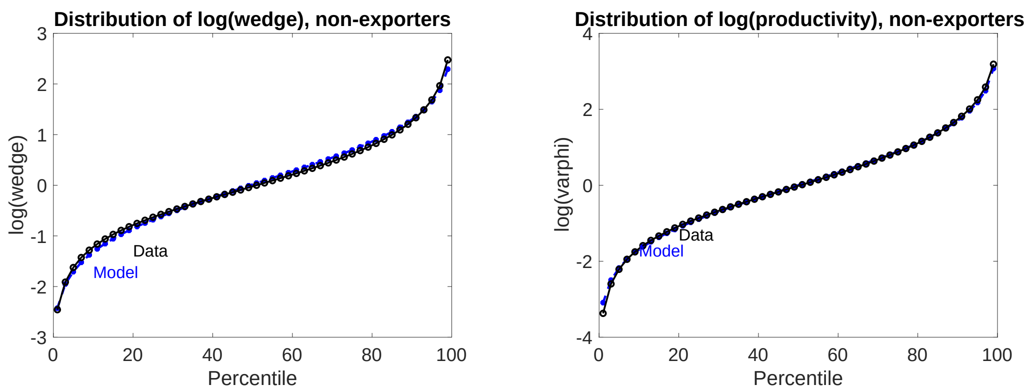
Some of the moments are non-targeted, including TFPR and TFPQ within each group, exporters and non-exporters, and among exporters. The export intensity is negatively correlated with both TFPR and TFPQ in the data. Our model matches these non-targeted moments very well.

Table A-1: Other Moments

	Data	Model
Implied moments		
TFPQ gap (ex−nonex)	0.17	0.18
TFPR gap (ex−nonex)	−0.06	-0.06
Export intensity	0.47	0.47
Std. value added	1.19	1.19
Corr (value added, TFPQ)	0.77	0.77
Corr (value added, TFPR)	0.45	0.45
Corr (value added, ex-int)	0.08	0.02
Corr (value added, ex-part)	0.17	0.18
Non-targeted moments		
Among Exporters		
Std. value added	1.20	1.36
Std. TFPQ	1.25	1.34
Corr (ex. intensity, TFPQ)	−0.13	-0.17
Corr (ex. intensity, TFPR)	−0.06	-0.03
Among Non-Exporters		
Std. value added.	1.16	1.08
Std. TFPQ.	1.34	1.31
Std. TFPR	0.96	0.98
Corr (TFPR, TFPQ)	0.93	0.93

Note: Data moments are for 2005 Chinese National Bureau of Statistics. Value added, TFPR, and TFPQ are logged. Corr denotes correlation, Std for standard deviation, ex for export, ex.intensity for export intensity, ex-part for export participation. TFPR gap is the difference between the average TFPR of exporters and that of non-exporters. Similarly for the TFPQ gap.

Figure A-7: Data point estimated τ and φ comparing with the Model



(a) $log(\tau)$ (b) $log(\varphi)$

Panel (a) of Figure A-7 presents the distribution of domestic wedge τ and productivity

φ, which are backed out using a near non-parametric method, as described in the main text. In this method, we make no assumptions about the distribution of productivity and wedges in the data. Nonetheless, the comparison between the model and data distributions indicates a close match, as illustrated in Figure A-7. The standard deviation of $\log(\varphi)$ is 1.36 in the data and 1.35 in the model, while the standard deviation of $\log(\tau)$ is 1.01 in the data and 1.03 in the model. Moreover, the correlations between productivity and wedge are also comparable, with a value of 0.92 in the data and 0.93 in the model.

G Heterogeneous trade costs model

In this section, we re-estimate the *hetero-trade-costs model*, which replace the firm-specific export taxes with firm-specific iceberg trade cost and firm-specific fixed cost of exporting. There is tension in estimating this model, and the new estimations have a bit worse match to the data. Below, we explain the tension and go over the estimation results in Table A-2.

In our benchmark model, wedges in export, τ_{ex}, help the model match the distribution of exporters' TFPR, and wedges in fixed exporting cost, τ_{fx}, help the model explain the export participation pattern including their correlations with TFPR. And τ_{fx} does not enter the calculation of exporters' TFPR. In the hetero-trade-costs model, τ_{ex} and τ_{fx} are 'technology' factors. For exporters, we need to rely on their domestic wedges τ and high fixed costs f, f_x to generate the observed standard deviation of $TFPR$ and its correlations with export. As a result, the model generates either too lower dispersion of TFPR for exporters or too strong correlations between TFPR and export participation.

To make it clear, we write down the solution for the hetero-trade-costs model here (τ_{ex} and τ_{fx} are 'technology' factors). An exporter i's optimal labor, sales, and export intensity are given by

$$\ell_i = \left[\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} P^{\sigma} Q w^{-\sigma}\right] \varphi_i^{\sigma-1}\tau_i^{-\sigma} + \left[\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} P_f^{\sigma} Q_f w^{-\sigma}\tau_x^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_{ex,i}^{1-\sigma} + f + \tau_{fx,i} f_x$$

$$pq_i = \left[\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} P^{\sigma} Q w^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_i^{1-\sigma} + \left[\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} P_f^{\sigma} Q_f w^{1-\sigma}\tau_x^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_{ex,i}^{1-\sigma}$$

$$\text{export intensity}_i \equiv ex_i = \frac{pq_{ex,i}}{pq_i} = \frac{1}{1 + \frac{P^\sigma Q}{P_f^\sigma Q_f}\left(\tau_x \frac{\tau_{ex,i}}{\tau_i}\right)^{\sigma-1}}.$$

Exporter's TFPR is an arithmetic weighted average of its $TFPR_d$ for domestic production and $TFPR_x$ for foreign production,

$$TFPR_i = \frac{pq_{d,i} + pq_{ex,i}}{\ell_{d,i} + \ell_{ex,i}} = \frac{1}{\frac{\ell_{d,i}}{pq_i} + \frac{\ell_{ex,i}}{pq_i}} = \frac{1}{(1 - ex_i)\frac{1}{TFPR_{d,i}} + ex_i \frac{1}{TFPR_{ex,i}}}. \tag{A.38}$$

Using our model, we can further write $TFPR_d$ and $TFPR_x$ as

$$TFPR_{d,i} = \frac{pq_{d,i}}{\ell_{d,i}} = \frac{\left[\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} P^\sigma Q w^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_i^{1-\sigma}}{\left[\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} P^\sigma Q w^{-\sigma}\right] \varphi_i^{\sigma-1}\tau_i^{-\sigma} + f} = \left(\frac{\sigma w}{\sigma - 1}\right)\left(\frac{\tau_i}{1 + \zeta_d \varphi_i^{1-\sigma}\tau_i^\sigma f}\right)$$

$$TFPR_{ex,i} = \frac{pq_{ex,i}}{\ell_{ex,i}} = \frac{\left[\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} P_f^\sigma Q_f w^{1-\sigma}\tau_x^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_{ex,i}^{1-\sigma}}{\left[\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} P_f^\sigma Q_f w^{-\sigma}\tau_x^{1-\sigma}\right] \varphi_i^{\sigma-1}\tau_{ex,i}^{1-\sigma} + \tau_{Fx,i} f_x} = \left(\frac{\sigma w}{\sigma - 1}\right)\left(\frac{1}{1 + \zeta_x \tau_{fx,i}(\varphi_i/\tau_{ex,i})^{1-\sigma} f_x}\right)$$

where ζ_d and ζ_x depend on the aggregate variables of P, Q, P_f, Q_f. Note that not like domestic distortion τ_i, the iceberg cost $\tau_{ex,i}$ does not show up in the numerator of $TFPR_{ex,i}$.

It is easy to see that without fixed exporting cost $f_x = 0$, $TFPR_{ex}$ is constant across exporters, and we need to use domestic distortion τ_i to generate both non-exporters and exporters $TFPR$. To be able to match both, we also need a high fixed exporting cost f_x and large standard deviation of $\tau_{fx,i}$ and $\tau_{ex,i}$ so that we can generate disperse enough $TFPR_{ex,i}$ to help us match both exporters' and non-exporters' $TFPR$ dispersion.

Large f_x and large standard deviation of $\tau_{fx,i}$ can fix the TFPR dispersion for exporters. However, there is another challenge in matching the correlation between export participation/intensity with $TFPR$. Consider the export participation rate. The export cutoff of firm i does not depend on its domestic wedge τ_i but exporting costs:

$$\varphi_{x,i}^* = \left[\frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1} w^{\frac{\sigma}{\sigma-1}} \tau_x f_x^{\frac{1}{\sigma-1}} (P_f^\sigma Q)^{\frac{1}{1-\sigma}}\right] \tau_{ex,i}\tau_{fx,i}^{\frac{1}{\sigma-1}} \equiv \zeta \tau_{ex,i}\tau_{fx,i}^{\frac{1}{\sigma-1}}.$$

Let Φ be the conditional distribution of φ, the export participation rate of firm i is $1 -$

$\Phi\left[\zeta\tau_{ex,i}\tau_{fx,i}^{\frac{1}{\sigma-1}}\right]$, which decreases with the firm's iceberg $\tau_{ex,i}$ and fixed trade cost $\tau_{fx,i}$.

Hence, a lower $\tau_{ex,i}$ or $\tau_{fx,i}$ pushes up both export participation and $TFPR_{ex,i}$ of firm i. This generates a force to make $TFPR_{ex,i}$ and export participation positively correlated, which is counterfactual. In contrast, in our benchmark model, $\tau_{fx,i}$ is not part of labor and does not show up in $TFPR_{ex,i}$. Furthermore, $\tau_{ex,i}$ is a wedge and also shows up in the numerator of $TFPR_{ex,i}$. Hence it is easier for our benchmark model to produce a negative correlation between $TFPR$ and export participation.

In addition, a larger variation in the domestic wedge τ and stronger positive correlations between τ_i and either $\tau_{ex,i}$ or $\tau_{fx,i}$ can lead to a higher dispersion of TFPR, as well as a negative correlation between TFPR (when τ_i is low) and export participation (when trade cost $\tau_{ex,i}$ is low). However, first, a very positive relationship between export intensity and TFPR ensues. Second, this suggests that heavily subsidized domestic firms are more technologically advanced when it comes to exporting, which we interpret as them also receiving subsidies for their exports in our benchmark.

In summary, it is hard for the estimation of hetero-iceberg model to match the dispersion of exporters' TFPR and the observed correlations between TFPR and trade. We ran estimations using the simulated method of moments in Matlab, and we tried with various initial guesses under global search method that allows for a broad range of parameter searches. The last column of Table A-2 presents the best estimation.

H Comparative Static: 1998 vs 2005

In this section, we investigate the factors behind the changes in welfare when the economy transitions from the 1998 scenario to our benchmark 2005 scenario. We achieve this by altering each parameter from its 1998 value to its corresponding value in 2005, one at a time, and measuring the resulting welfare gain or loss. Table A-3 displays the changes in the distribution parameters, namely, σ_φ, σ_τ, $\sigma_{\tau_{ex}}$, $\rho_{\varphi,\tau_{ex}}$, and $\sigma_{\tau_{fx}}$. For example, the column titled "lower σ_φ" represents the change in σ_φ from 1.34 in the 1998 calibration to 1.13 in the benchmark calibration. We do not provide a comparative analysis for the other distribution parameters since they remain almost the same in both 1998 and 2005 scenarios. For each

Table A-2: Data, Benchmark, and Alternative Models

	Data	Bench	No τ_{fx} $\tau \neq \tau_{ex}$	No τ_{fx} $\tau = \tau_{ex}$	Heter-trade-cost
Parameters					
Fixed cost of producing f		0.07	0.06	0.09	0.12
Fixed cost of export f_x		0.09	0.05	0.42	0.20
Iceberg trade cost τ_x		2.85	3.07	1.85	3.45
Mean foreign prod $\mu_{f\varphi}$		2.47	2.37	3.92	5.32
Std. productivity σ_φ		1.36	1.39	1.33	1.40
Std. distortion on home sales σ_τ		1.13	1.15	1.01	0.90
Std. distortion or cost on export sales $\sigma_{\tau_{ex}}$		1.01	0.96	1.01	1.60
Corr(φ, τ) $\rho_{\varphi,\tau}$		0.90	0.90	0.90	0.90
Corr(φ, τ_{ex}) $\rho_{\varphi,\tau_{ex}}$		0.62	0.56	0.90	0.60
Corr(τ, τ_{ex}) $\rho_{\tau,\tau_{ex}}$		0.64	0.57	1.00	0.70
Std. distortion or cost on export fixed cost $\sigma_{\tau_{fx}}$		0.62	–	–	1.60
Corr(φ, τ_{fx}) $\rho_{\varphi,\tau_{fx}}$		0.30	–	–	0.40
Corr(τ, τ_{fx}) $\rho_{\tau,\tau_{fx}}$		−0.10	–	–	0.40
Corr(τ_{ex}, τ_{fx}) $\rho_{\tau_{ex},\tau_{fx}}$		0.01	–	–	0.17
Targeted Moments					
Fraction of firms producing	0.85	0.86	0.84	0.85	0.84
Fraction of firms exporting	0.30	0.30	0.30	0.30	0.30
Import share	0.23	0.23	0.23	0.23	0.23
Relative GDP of U.S. to China	1.79	1.79	1.79	1.79	1.79
Std. TFPQ	1.32	1.32	1.32	1.33	1.36
Std. TFPR	0.94	0.95	0.95	0.94	0.84
Std. TFPR, exporters	0.88	0.87	0.87	0.91	0.69
Corr (TFPR, TFPQ)	0.91	0.92	0.91	0.91	0.93
Corr (TFPR, TFPQ), exporters	0.90	0.89	0.89	0.97	0.87
Std. export intensity	0.38	0.33	0.33	0.00	0.28
Corr (ex. participation, TFPQ)	0.06	0.06	0.23	0.06	0.10
Corr (ex. participation, TFPR)	−0.03	−0.03	0.10	−0.31	−0.04
Corr (ex. intensity, TFPQ)	0.01	−0.01	0.09	0.06	0.02
Corr (ex. intensity, TFPR)	−0.04	−0.03	0.05	−0.31	−0.05
Non-Targeted Moments					
TFPQ gap (ex−nonex)	0.17	0.18	0.66	0.17	0.30
TFPR gap (ex−nonex)	−0.06	−0.06	0.22	−0.63	−0.08
Export intensity	0.47	0.47	0.40	0.33	0.41
Std. value added	1.19	1.19	1.20	1.21	1.33
Corr (value added, TFPQ)	0.77	0.77	0.77	0.77	0.88
Corr (value added, TFPR)	0.45	0.45	0.44	0.45	0.64
Corr (value added, ex-int)	0.08	0.02	0.12	0.60	0.11
Corr (value added, ex-part)	0.17	0.18	0.34	0.60	0.26
Among Exporters					
Std. value added	1.20	1.36	1.24	0.98	1.48
Std. TFPQ	1.25	1.34	1.26	1.33	1.26
Corr (ex. intensity, TFPQ)	−0.13	−0.17	−0.19	−0.001	−0.11
Corr (ex. intensity, TFPR)	−0.06	−0.03	−0.06	−0.001	−0.06
Among Non-Exporters					
Std. value added.	1.16	1.08	1.07	0.97	1.19
Std. TFPQ.	1.34	1.31	1.30	1.33	1.40
Std. TFPR	0.96	0.98	0.97	0.90	0.89
Corr (TFPR, TFPQ)	0.93	0.93	0.93	0.98	0.96
Distance with data		0.002	–	–	0.010

Note: TFPR and TFPQ are logged. Corr denotes correlation, Std for standard deviation, 'intensity' for export intensity, 'part.' for export participation. For '(No τ_{fx}, $\tau \neq \tau_{ex}$)', we estimate the model with no τ_{fx} but allowing for differential τ_{ex} and τ. In this case, we do not target the four trade correlations. For '(No τ_{fx}, $\tau = \tau_{ex}$)', we estimate the model with no τ_{fx} and $\tau = \tau_{ex}$. In this case, we do not target within-group distributions of TFPR and TFPQ and the four trade correlations. For 'hetero-trade-costs', we estimate a case without export wedges but with heterogeneous iceberg and fixed exporting costs.

scenario, we report the key moments and the welfare relative to our benchmark calibrated 2005 data.

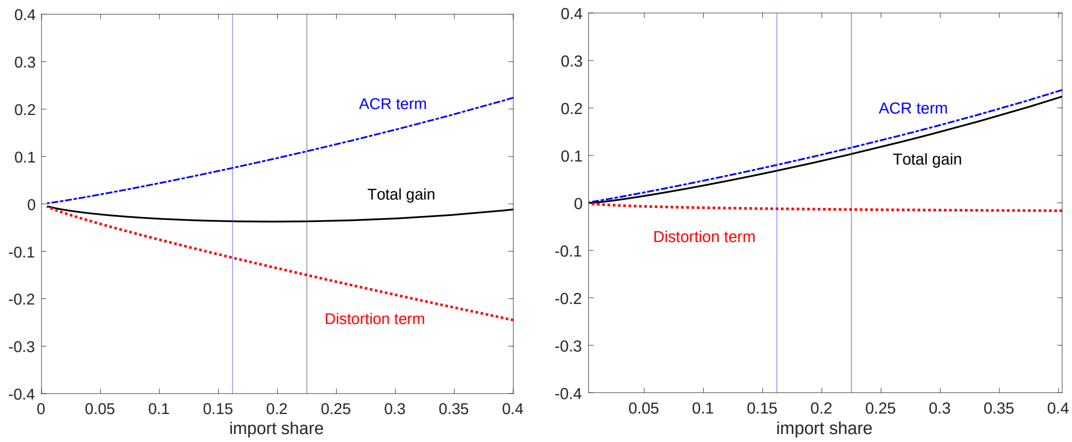
Table A-3: Comparative Static: 1998 to 2005

			98-model Comparative Static				
	05-model	98-model	lower σ_{φ}	lower σ_{τ}	lower $\sigma_{\tau_{ex}}$	lower $\rho_{\varphi,\tau_{ex}}$	increase $\sigma_{\tau_{fx}}$
98 value			1.59	1.34	1.11	0.68	0.56
05 value			1.36	1.13	1.01	0.62	0.62
Welfare wrt 98 (%)	57		−66	68	4.8	3.1	−0.04
Key Moments							
Import share	0.23	0.16	0.18	0.12	0.16	0.19	0.16
Std. TFPQ	1.32	1.53	1.26	1.58	1.52	1.52	1.53
Std. TFPR	0.95	1.13	1.03	1.06	1.12	1.12	1.13
Corr (TFPR, TFPQ)	0.92	0.92	0.90	0.92	0.92	0.92	0.92
Std. export intensity	0.33	0.35	0.36	0.27	0.35	0.33	0.35
Among Exporters							
Std. TFPQ.	1.34	1.52	1.25	1.62	1.48	1.46	1.52
Std. TFPR.	0.87	1.02	0.92	1.04	0.97	1.00	1.02
Corr (TFPR, TFPQ)	0.89	0.92	0.89	0.93	0.91	0.90	0.92
Among Non-Exporters							
Std. TFPQ.	1.31	1.53	1.27	1.56	1.51	1.51	1.53
Std. TFPR	0.98	1.16	1.07	1.07	1.15	1.15	1.16
Corr. (TFPR, TFPQ)	0.93	0.92	0.91	0.93	0.92	0.93	0.92
Trade Correlations							
Corr (part., TFPQ)	0.06	0.09	−0.01	0.10	0.17	0.14	0.09
Corr (part., TFPR)	−0.03	0.01	−0.09	−0.01	0.09	0.03	0.01
Corr (intensity, TFPQ)	−0.01	0.01	−0.02	−0.04	0.06	0.06	0.01
Corr (intensity., TFPR)	−0.03	−0.003	−0.02	−0.09	0.06	0.02	−0.01

Notte that the first column in the table, labeled as "05-model," presents the benchmark moments. The second column, labeled as "98-model," displays the moments obtained from the 1998 calibration. The remaining columns (3-7) present the moments obtained by changing only one parameter from the 98 calibrated value to the benchmark calibrated value while keeping all other distribution parameters the same as in 1998. For instance, the column labeled as "lower σ_{φ}" refers to the change in σ_{φ} from its value of 1.34 in the 98 calibration to 1.13 in the benchmark calibration. The table considers the comparative analyses in distribution parameters of σ_{φ}, σ_{τ}, $\sigma_{\tau_{ex}}$, $\rho_{\varphi,\tau_{ex}}$, and $\sigma_{\tau_{fx}}$. All other distribution parameters are similar in 1998 and in 2005. The statistics "welfare wrt. 98 (%)" is the difference between the welfare in each scenario and the welfare in 1998.

Figure A-8 plots the gain from trade and the decomposition. The left panel is when underlying firm distributions of productivity and wedges are fixed as in 2005, the relative large std. of exporting wedge comparing to productivity generate large negative fiscal externality. The right panel is the gain from trade when underlying firm distributions of productivity and wedges are fixed as in 1998, fiscal externality is small, there are welfare gains with trade cost reduction.

Figure A-8: Welfare Gain From Trade



(a) 2005 Calibration (Bench)

(b) 1998 Calibration

I Discussions

I.1 Impact of Home Distortions on Foreign Welfare

In the benchmark, foreign gain from trade is about 9% with or without Home distortions, though its gains is slightly lower when Home features distortions. Without distortions at Foreign, Foreign welfare still satisfies MR decomposition. But Home distortions have impact on Foreign's domestic sales share, entry, and cutoffs. To understand the impact, let's revisit Foreign welfare. From consumers' budget constraint and firms' free-entry condition, we can write Foreign welfare as

$$W_f = C_f = \frac{w_f L_f}{P_f},$$

where w_f and P_f are Foreign wage and consumer price, respectively. We can further write down Foreign aggregate price index as

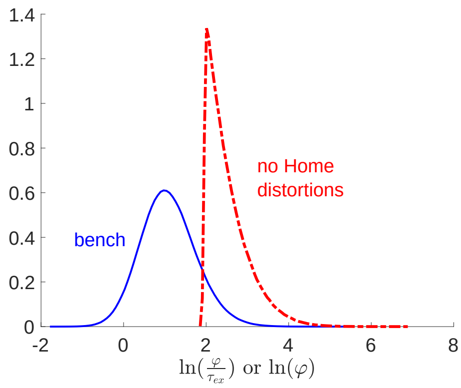
$$P_f = \left[M_{ef} \int_{\varphi_f^*} \left(\frac{\sigma}{\sigma - 1} \frac{w_f}{\varphi} \right)^{1-\sigma} dG_f + M_e \int_{\varphi_x^*(\tau_{ex}, \tau_{fx})} \left(\frac{\sigma}{\sigma - 1} \frac{w \tau_x \tau_{ex}}{\varphi} \right)^{1-\sigma} dG \right]^{\frac{1}{1-\sigma}}.$$

Plugging P_f back to the welfare equation and reorganizing it, we have

$$W_f = \frac{\sigma - 1}{\sigma} L_f \left[M_{ef} \int_{\varphi_f^*} \varphi^{\sigma-1} dG_f + M_e \tau_x^{1-\sigma} \int_{\varphi_x^*(\tau_{ex}, \tau_{fx})} \left(\frac{w_f}{w} \frac{\varphi}{\tau_{ex}} \right)^{\sigma-1} dG \right]^{\frac{1}{\sigma-1}}. \tag{A.39}$$

Hence, Home distortion affects foreign welfare through the import prices, the relative wage w_f/w, Foreign producing cutoff φ_f^*, and Home exporting cutoff φ_x^*. The import prices are proportional to firms' marginal cost of producing τ_{ex}/φ, or they are inversely related to firms' effective productivity φ/τ_{ex}. The higher the average effective productivities, the lower the import prices, the higher the Foreign welfare. Also, the higher the relative wage, the higher the Foreign welfare.

Figure A-9: Distribution of Foreign Imported Goods



The prices Foreign faces are lower were Home firms to be taxed less (low τ_{ex}); on the other hand, some low-φ hence high-marginal-cost Home firms will be selected into exporting, making the Foreign's import prices higher. Figure A-9 depicts the distribution of the effective productivities (φ/τ_{ex}) of Foreign country's imported goods from Home country. The blue-solid line is for the benchmark, and the red-dashed line is for no Home distortions. The differences of the two lines reflect the different underlying distributions of φ/τ and φ, as well as the different cutoffs of Home exporting φ_x^* with and without distortions. The benchmark distribution is to the left of that when Home faces no distortions. These low effect productivity (or high marginal costs) tend to reduce Foreign welfare.

Meanwhile, Home distortions also have general equilibrium effect on relative wages. When there are Home distortions, the relative higher demand for foreign products induces a higher Foreign wage. Without Home distortions, its efficiency improves, and the Foreign wage would be lower. Under our estimation, the relative Foreign wage under Home distortions is about twice higher than that under no distortions.

In summary, Home distortions have two opposing effects on Foreign welfare. On the one hand, distortions push up the import prices (through low effective productivity or high marginal cost) of Foreign and lower Foreign welfare. On the the hand, distortions raise Foreign wage and welfare. These two effects cancel out in our estimation and lead to a similar welfare gain for Foreign country with or without Home distortions. One factor affects the race of the two effects is the dispersion of τ_{ex}. More dispersed τ_{ex} pushes up more the import prices of Foreign and leads to a lower Foreign welfare under Home distortions.

I.2 Imbalanced Trade

To see the quantitative impact of trade imbalances between China and U.S., we follow Dekle, Eaton, and Kortum (2007) and impose the observed imbalances in our equilibrium condition. Due to wealth transfer from trade imbalance, we would expect a decrease in Home import share and welfare and an increase in foreign wage. Quantitatively, under our benchmark parameters and trade surplus at Home (China), foreign wage increases by 1.7% and Home welfare in the open economy decreases by 4.7% relative to our benchmark. This decline in welfare mainly comes from the wealth transfers from Home's trade surplus, as in Dekle, Eaton, and Kortum (2007) . Adding trade surplus to Home country slightly affects our model moments. We also reestimate the model parameters, and the quantitative results are similar as the case without reestimation. (i.e., Home has lower welfare than our benchmark.)

Note that our model is a static one. Under a dynamic model, a country that runs trade surplus in the current period should run trade deficits in the future. Thus, the net present value of trade imbalance should be close to zero. Let β be countries' discount factor and r the world interest rate. Under a complete market model and $\beta(1+r)=1$, the country's overall welfare gain or loss from trade would be roughly the same as our benchmark result.

I.3 Iceberg Cost vs Tariff

The benchmark model considers idiosyncratic distortions that are taxes/subsidies and trade costs that are pure resource losses. Here we discuss some alternatives.

I.3.1 Domestic distortion takes the form of iceberg cost

We'd like to point out that the model with an iceberg-cost type of distortion does not produce any wedges. In this case, distortion works like a productivity shock. Hence, the welfare decomposition is equivalent to ACR or MR. There is alway gains from trade. Most importantly, the welfare decomposition has no distortion term. In other words, using aggregates as in the literature can capture well the gains from trade. Let us elaborate on these points below.

To clearly make the point, we now present a closed economy, where distortions are modelled in the same way as the iceberg trade cost. Specifically, to produce q units, the firm has to use $\ell_v = \tau q/\varphi$ units of variable labor plus the fixed cost, where τ is the distortion and φ is the productivity. A intermediate-good firm (φ, τ) solves the following problem

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

subject to the demand function $q = \frac{p^{-\sigma}}{P^{-\sigma}} Q$. We can characterize the optimal price p, variable labor ℓ_v, output q, and revenue pq as

$$p = \frac{\sigma}{\sigma - 1} w \left(\frac{\varphi}{\tau}\right)^{-1}, \tag{A.40}$$

$$\ell_v = \left[\left(\frac{\sigma}{\sigma - 1}\right)^{-\sigma} (P^\sigma Q) w^{-\sigma}\right] \left(\frac{\varphi}{\tau}\right)^{\sigma - 1}, \tag{A.41}$$

$$q = \left[\left(\frac{\sigma}{\sigma - 1}\right)^{-\sigma} (P^\sigma Q) w^{-\sigma}\right] \left(\frac{\varphi}{\tau}\right)^{\sigma}, \tag{A.42}$$

$$pq = \left[\left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} (P^\sigma Q) w^{1-\sigma}\right] \left(\frac{\varphi}{\tau}\right)^{\sigma - 1}, \tag{A.43}$$

It is easy to see that all the endogenous variables here (p, ℓ_v, q, pq) only depend on the ratio of φ to τ, or the effective productivity $\tilde{\varphi} = \varphi/\tau$. Note that in our benchmark model with 'tax' style of distortion, the optimal p, q, and pq take the same formula as above. However, optimal variable labor is given by,

$$\ell_v^{bench} = \left[\left(\frac{\sigma}{\sigma - 1} \right)^{-\sigma} (P^\sigma Q) w^{-\sigma} \right] \varphi^{\sigma-1} \tau^{-\sigma}. \tag{A.44}$$

The distortion in our benchmark model is equivalent to a labor wedge. For one unit of labor, households receive w unit of payment, but firms pay for $w\tau$. With this one unit of labor, firms produce φ unit of goods. The marginal product of variable labor $pq/\ell_v^{bench} = \frac{\sigma}{\sigma-1} w\tau$ is firm-specific and is not equalized across firms. In contrast, the iceberg cost behaves like a productivity. For one unit of labor, households receive w and firms pay for w, there is no wedge between them. All firms have the same marginal product of variable labor, $pq/\ell_v = \frac{\sigma}{\sigma-1} w$. However, with one unit of labor, firms can only produce φ/τ unit of goods, which costs extra resources. However, there is no efficiency loss from misallocation (wedge) as in HK.

Hence an open-economy model under iceberg-type of distortion is equivalent to a Melitz model with productivity distribution on $\tilde{\varphi} = \varphi/\tau$. If $\tilde{\varphi}$ follows a Pareto distribution, we reach the ACR result, where the import share and trade elasticity can forecast the gain from trade. We do not need the underlying distribution of physical productivity φ and true distortion τ for measuring the gain from trade. If $\tilde{\varphi}$ follows a general distribution, the MR results hold. Still, there is no reallocation term as in our theory.

In summary, the iceberg type of distortion shows up like a technology shock. It lowers welfare because firms have to use more labor to produce the same unit of output. There are deadweight losses. However, the iceberg cost does not generate misallocations across firms. Hence the welfare decomposition does not consist a reallocation term to reflect such misallocation. In contrast, our benchmark aims to examine the implication of HK type of distortion on gain from trade. This type of distortion generates misallocation showing up as wedges across firms.

I.3.2 Tariff instead of iceberg trade cost

Tariff works like the distortion in our benchmark and generates a wedge between sales and input share, which shows up in the welfare decomposition. In this part, we first show how tariff affects our equilibrium conditions. We then present the welfare decomposition under tariff. Lastly, we compare quantitatively the results under tariff and under iceberg trade cost.

Let τ_m denote tariff. First, tariffs enter the price index the same way as an iceberg trade cost:

$$P^{1-\sigma} = con_p \times \left[M \frac{\int \int_{\varphi^*(\tau)}^{\infty} (\frac{\varphi}{w\tau})^{\sigma-1} g(\varphi,\tau)\, d\varphi d\tau}{\int \int_{\varphi^*(\tau)}^{\infty} g(\varphi,\tau)\, d\varphi d\tau} + M_f \frac{\int \int_{\varphi_{xf}^*(\tau)}^{\infty} (\frac{\varphi}{w_f \tau_m \tau})^{\sigma-1} g_f(\varphi,\tau)\, d\varphi d\tau}{\int \int_{\varphi_f^*(\tau)}^{\infty} g_f(\varphi,\tau)\, d\varphi d\tau} \right].$$

Second, the free entry condition is different. Now tariff enters the formula in a similar way as output distortions. In particular, it is $\tau_{mf}^{-\sigma}$ that enters, and it is $\tau_x^{1-\sigma}$ in the iceberg cost case.

$$\begin{aligned} & w^{1-\sigma} \left[P^{\sigma} Q \int \int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau + P_f^{\sigma} Q_f \tau_{mf}^{-\sigma} \int \int_{\varphi_x^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} g(\varphi,\tau) d\varphi d\tau \right] \\ & = \sigma^{\sigma} (\sigma-1)^{1-\sigma} \left(w f_e + w f \omega_e + w f_x \omega_x \right). \end{aligned}$$

If we assume the two countries charge the same τ_m, the trade balance condition is the same as before. With different tariffs across countries, total expenditure in Home could be different from its total revenues. In this case, the balanced trade condition becomes

$$\begin{aligned} & P_f^{\sigma} Q_f M \int \int_{\varphi_x^*(\tau)}^{\infty} \left(\frac{w\tau}{\varphi} \right)^{1-\sigma} \tau_{mf}^{-\sigma} \mu(\varphi,\tau)\, d\varphi d\tau \\ & = P^{\sigma} Q M_f \int \int_{\varphi_{xf}^*(\tau)}^{\infty} \left(\frac{w_f \tau_m \tau}{\varphi} \right)^{1-\sigma} \tau_m^{-\sigma} \mu_f(\varphi,\tau)\, d\varphi d\tau, \end{aligned}$$

where τ_{mf} is Foreign tariff on imported Home goods.

Welfare decomposition To show that tariff is different from iceberg trade cost, we drive a formula without any other distortions but tariff. This model is the same as Melitz except that we replace the iceberg trade cost with tariff. In this case, the welfare formula becomes

$$d\ln W = \frac{1}{\gamma_\lambda + \sigma - 1}\Big[- d\ln\lambda + d\ln M_e + \left(\sigma - 1 + \frac{\sigma\gamma_\lambda}{\sigma - 1}\right)(-d\ln\lambda + d\ln S)\Big]$$

where λ is domestic sales share, S domestic input share, γ_λ is the elasticity to cumulated sales share with respect to cutoff and is evaluated at domestic cutoff.

On the one hand, tariff creates a gap between domestic sales and input share, which does not show up in the case with iceberg cost as in ACR or MR. With tariff, even if firms' productivities follow a Pareto distribution, we still cannot only use the change of domestic sales share (or import share) and trade elasticities to infer the welfare change after trade.

On the other hand, tariff is a tax and incentivized Home firms to shift labor toward domestic production. This leads to a positive reallocation term since the change of domestic input share tend to be larger than that of sales share, i.e. $d\ln S \geq d\ln\lambda$. In contrast, in our benchmark model, by selection, firms with large export 'subsidies' τ_{ex} will employ more labor and export more. This leads to larger increase in labor share than sales share for exporting firms, or the change of domestic labor share is smaller sales share, $d\ln S \leq d\ln\lambda$. Hence, tariff works opposite to the export subsidies in our benchmark model.

We can also prove that the welfare expression is the same as in our benchmark when there are various distortions $(\tau, \tau_{ex}, \tau_{fx})$.

Quantitative results We now compare quantitatively the welfare impact of tariff and iceberg trade cost. To illustrate their differences, we first follow Baqaee and Farhi (2021) and compare two counterfactuals on our benchmark results, a 10% universal increase in tariff and a 10% universal increase in iceberg trade cost. These changes are for both the home and foreign country. We also consider a model with both tariff and the iceberg trade cost, and we take the tariffs from the data and reestimate the iceberg trade cost together with other parameters.

Table A-4 reports the gain from trade and welfare decomposition for the home country in these experiments together with our benchmark. Without distortions, both the increase in iceberg trade cost and the increase in tariff lower the gain from trade. The reduction is larger for the iceberg cost, reflecting its deadweight loss. With distortions, higher iceberg cost lowers the trade share, which in turn lowers the magnitude of ACR and reallocation term. Overall, the welfare gain from trade is lower than the benchmark, decreasing to -1.66% from the benchmark -1.18%.

An increase in tariff from the benchmark also reduces the incentive to trade and lowers the ACR term in a similar magnitude as in the case of increasing trade cost. However, the reallocation term becomes less negative, -8.62% versus -11.16% in the trade cost case. Hence the gain from trade becomes larger, 0.75%. Tariff increases Home welfare because it corrects some of the distortions at Home. By selection, exporters tend to have low τ_{ex} and use too larger share of labor relative to the output share that exporters produce. Hence a positive tax like tariff helps cancel out the exporters' benefit from τ_{ex} and reduces the gap between input and sales share.

The last column of Table A-4 reestimates the model with tariffs from the data. The average Chinese tariff is 9.55% and the US tariff is 3.33%, both for the manufacturing sector in 2005. We estimate the iceberg trade cost together with other parameters in our model, similar in our benchmark. In particular, the reestimation guarantees an import share of 22.5% as in the data. And the ACR term is similar to the benchmark model, both around 12.5%. As we discussed above, tariff tends to correct the exacerbated misallocation from trade, the reallocation becomes smaller, about 3% higher than the benchmark. In total, the gain from trade is 1.82%.

Overall, all these results have the outcome of large negative reallocation. Using the aggregates only with ACR term will greatly overestimate the gain from trade. The overestimation are about 10 times the true gain from trade in the model.

J TFPR and TFPQ in the Data and Measurement Error

We find large dispersions in measured TFPR in China, similar to the levels in HK for the year 1998 and 2007. TFPR can be written into two terms: revenue product of labor $ARPL_{ji} = p_{ji}q_{ji}/\ell_{ji}$ and revenue product of capital $ARPK_{ji} = p_{ji}q_{ji}/k_{ji}$, i.e. for any firm i

Table A-4: Welfare Implications of Trade Cost and Tariff

	Bench	Increase in trade cost (10% universal)	Increase in tariff (10% universal)	2005 Tariff (reestimation)
Home country				
Gain from trade	−1.18	−1.66	0.75	1.82
Welfare decomp.				
ACR term	12.53	10.34	10.22	12.49
Reallocation	−12.94	−11.16	−8.62	−10.14
No Home distortions				
Gain from trade	3.31	2.72	3.29	4.02

Note: All numbers are in percent.

in industry j,

$$\log(TFPR_{ji}) = \alpha_j \log(ARPL_{ji}) + (1-\alpha_j)\log(ARPK_{ji}).$$

where α_j is the industry specific labor share. Both measured ARPL and ARPK have come down over time, between 1998 and 2007, as evident in Table A-5. There is also greater dispersion in the average product of capital than there is in the average product of labor.

Table A-5: Dispersion of ARPK and ARPL

	1998	2001	2004	2007
std(ARPK)	1.348	1.306	1.241	1.185
std(ARPL)	1.184	1.039	0.940	0.923

We next turn to investigating further what factors are systematically related to measured TFPR. First, TFPR is highly correlated with TFPQ, as shown graphically in Figure A-10. Second, we conduct the regression analyses of measured TFPR on TFPQ and a set of variables like age, ownership, exporter dummy with or without industry and location fixed effect. See Table A-6.

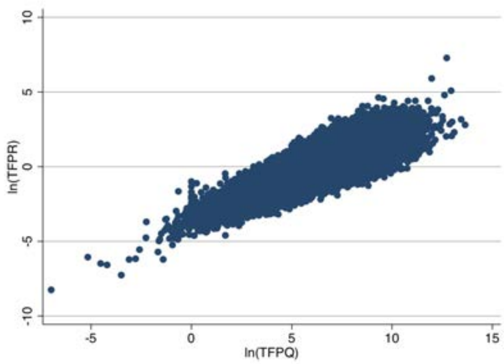
In all these regressions, the coefficient on firm TFPQ is large and significant; 1 percent increase in TFPQ is associated with about 60 percent increase in TFPR. Moreover, more than half of the variation in TFPR is explained by TFPQ alone. The positive relationship is consistent with the predictions of our model as showing in the model regression (Column 7). The same is true for the results on exporters: given TFPQ, firms must have lower taxes

Table A-6: TFPR Regressions

VARIABLES	(1) ln$(TFPR)$	(2) ln$(TFPR)$	(3) ln$(TFPR)$	(4) ln$(TFPR)$	(5) ln$(TFPR)$	(6) ln$(TFPR)$	(7) Extended model ln$(TFPR)$
ln$(TFPQ)$	0.574***	0.630***	0.635***	0.635***	0.635***	0.639***	0.648
	(243.5)	(235.9)	(243.2)	(241.6)	(248.4)	(261.6)	
Age				-0.00165***	-0.00163***	-0.00148***	
				(-9.736)	(-10.10)	(-10.05)	
SOE					-0.100***	-0.0930***	
					(-4.577)	(-4.481)	
Foreign owned					-0.230***	-0.156***	
					(-25.96)	(-24.60)	
Exporters						-0.213***	-0.241
						(-24.96)	
Constant	-3.502***	-3.296***	-3.236***	-3.209***	-3.131***	-3.129***	
	(-243.5)	(-106.2)	(-89.23)	(-87.12)	(-75.08)	(-77.04)	
Observations	1,587,629	1,587,629	1,479,528	1,478,648	1,478,648	1,478,648	
R-squared	0.739	0.812	0.822	0.823	0.831	0.837	
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 in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure A-10: Measured TFPR and TFPQ



on average in order to export, and have a lower TFPR. TFPR differences are also systematic related to firm characteristics: state-owned enterprises and Foreign-owned firms are subject to lower TFPR on average, given TFPQ.

Measurement error With the presence of fixed costs in producing and exporting in our model, the measured TFPR does not perfectly relate to the true wedges. In the data, there are other types of mismeasurements in output and input, which 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). Here we use Bils, Klenow, and Ruane (2017)'s method to detect measurement errors. We find that even taking out the standard measurement errors, there are still large distortions remaining among Chinese firms.

The main approach involves using panel data to estimate the true marginal product dispersion among operating firms, 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.[20] This 18% includes the mismeasurement of production inputs in the presence of fixed cost, which is accounted for in our benchmark.

Table A-7: Detecting Measurement Errors

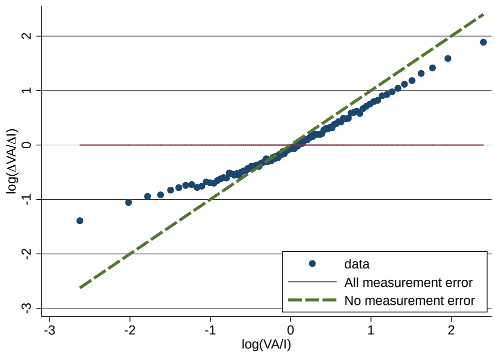
Average annual observation within firm				
std(ln(ARPK))	std(ln(ARPL))	$std(lnVA)$	$std(ln(VA/I))$	$corr(lnVA, ln(VA/I))$
1.19	0.96	1.19	0.94	0.4
		First level differences		
		2001	2004	2007
$std(ln(\triangle VA/\triangle K))$		1.82	1.78	1.76
$std(ln(\triangle VA/\triangle L))$		1.68	1.60	1.61
		Regression		
		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 (A.45). Robust t-statistics in parentheses.

[20] 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, but little for China.

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).

Figure A-11: Measured Marginal Product using First Differences vs TFPR



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 A-7 reports the statistics when we take the average within firms. The average standard deviation is 1.19 for the average product of capital and 0.96 for the average 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 the moments in year 2005. 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 A-7 for the year of 2001, 2004, and 2007. The dispersions are even higher than those

Table A-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.

in Table A-5 for the measured average product of inputs.

Moreover, the alternative measured marginal products are highly correlated with average products. Figure A-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 A-8. Note that without measurement errors, the two measures are perfectly correlated. For the case with only measurement error, the two measures have no correlation. Hence, the high correlation between the alternative measure and the average products suggest small measurement errors and a large distortion-induced misallocation.

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

$$\triangle\widehat{VA}_i = \Phi \cdot \log(TFPR_i) + \Psi \cdot \triangle\hat{I}_i - \Psi(1-\lambda) \cdot \log(TFPR_i) \cdot \triangle\hat{I}_i + D_s + \xi_i \tag{A.45}$$

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

Table A-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.

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 A-7. The implied λ is therefore 0.81. Hence, 81% of variation in $TFPR$ or average products is accounted for by distortions 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.[21] See Table A-9.

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.

K Endogenous Wedges

The benchmark model assumes exogenous distortions correlated with firm-level productivity. A possible scenario is that distortions are size-dependent, for instance, on firm revenue. David and Venkateswaran (2019) discusses how size-dependent policies can lead to some isomorphism with policies that are correlated with underlying productivity. In what follows, we assume that the distortions on domestic and foreign sales, τ and τ_{ex}, positively depend on a firm's sales with an elasticity of β:

$$\ln\tau = \beta\ln(pq) + \ln\varepsilon, \qquad \ln\tau_{ex} = \beta\ln(p_x q_x) + \ln\varepsilon_{ex}, \tag{A.46}$$

where ε and ε_{ex} are idiosyncratic distortions on domestic and export revenue and potentially correlate with the firm's productivity or the distortion on the fixed exporting cost. In this case, a firm's distortions endogenously change as firms expand or shrink. In equilib-

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

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

rium with the optimal production, we can show that

$$\ln \tau = \mu_c + \frac{\beta(\sigma - 1)}{1 - \beta + \sigma\beta} \ln \varphi + \frac{1}{1 - \beta + \sigma\beta} \ln \varepsilon + \frac{\beta}{1 - \beta + \sigma\beta} \ln(P^\sigma Q),$$

where μ_c is a constant. The case with $\beta = 0$ gets us back to the benchmark model. With size dependent policies, the distortion τ is endogenously correlated with productivity even if ε and φ are uncorrelated.[22]

Specifically, a new entrant firm draws a quadruple of productivity φ, wedge of domestic sales ε, wedge of foreign sales ε_{ex}, and wedge of fixed cost in foreign sales τ_{fx}, i.e. $(\varphi, \varepsilon, \varepsilon_{ex}, \tau_{fx})$, from a distribution with pdf $g(\varphi, \varepsilon, \varepsilon_{ex}, \tau_{fx})$ and cdf $G(\varphi, \varepsilon, \varepsilon_{ex}, \tau_{fx})$. Foreign firms draw the quadruple from a pdf g_f and cdf G_f. An exporting firm at Home solves the following problem

$$\max_{p_x, q_x} \frac{1}{\tau_{ex}} p_x q_x - \frac{w}{\varphi} \tau_x q_x - \tau_{fx} w f_x$$

subject to the foreign demand function $q_x = \frac{p_x^{-\sigma}}{P_f^{-\sigma}} Q_f$.

Let $\tilde{\sigma} \equiv \frac{\sigma}{1-\beta+\sigma\beta}$. The optimal exporting price and quantity is

$$p_x = \left[\frac{\tilde{\sigma}}{(\tilde{\sigma} - 1)} \frac{\varepsilon_{ex} w \tau_x}{\varphi} (P_f^\sigma Q_f)^\beta \right]^{\frac{\tilde{\sigma}}{\sigma}}$$
$$q_x = \left[\frac{\tilde{\sigma} - 1}{\tilde{\sigma}} \right]^{\tilde{\sigma}} \left(P_f^\sigma Q_f \right)^{\frac{\tilde{\sigma}-1}{\sigma-1}} \left[\frac{\varepsilon_{ex} w \tau_x}{\varphi} \right]^{-\tilde{\sigma}},$$

and the optimal profit of exporting is given by

$$\pi_x = \frac{1}{\tilde{\sigma} - 1} \left[\frac{\tilde{\sigma} - 1}{\tilde{\sigma}} \right]^{\tilde{\sigma}} (P_f^\sigma Q_f)^{\frac{\tilde{\sigma}-1}{\sigma-1}} (\frac{\varphi}{w\tau_x})^{(\tilde{\sigma}-1)} \varepsilon_{ex}^{-\tilde{\sigma}} - \tau_{fx} w f_x.$$

[22] In equilibrium, a firm chooses its price as $p = \frac{\sigma}{(\sigma-1)(1-\beta)} \tau(pq, \varepsilon) \frac{w}{\varphi}$, as if it faces a variable markup τ increasing with its revenue pq. Hence, the endogenous wedge model relates to the literature studying the welfare implications of variable markup, for example Feenstra and Weinstein (2017), Dhingra and Morrow (2019), and Edmond, Midrigan, and Xu (2018).

Cutoffs There are two cutoff productivities in home country, $\varphi^*(\tau)$ for entering the domestic market and $\varphi_x^*(\tau_{ex}, \tau_{fx})$ for entering the foreign market:

$$\varphi^*(\varepsilon) = \frac{\tilde{\sigma}^{\frac{\tilde{\sigma}}{\tilde{\sigma}-1}}}{\tilde{\sigma}-1} [wf]^{\frac{1}{\tilde{\sigma}-1}} [P^\sigma Q]^{-\frac{1}{\sigma-1}} w\varepsilon_{ex}^{\frac{\tilde{\sigma}}{\tilde{\sigma}-1}}$$

$$\varphi_x^*(\varepsilon_{ex}, \tau_{fx}) = \frac{\tilde{\sigma}^{\frac{\tilde{\sigma}}{\tilde{\sigma}-1}}}{\tilde{\sigma}-1} \left[wf_x\tau_{fx}\right]^{\frac{1}{\tilde{\sigma}-1}} \left[P_f^\sigma Q_f\right]^{-\frac{1}{\sigma-1}} (w\tau_x)\, \varepsilon_{ex}^{\frac{\tilde{\sigma}}{\tilde{\sigma}-1}}.$$

Free entry conditions The free entry condition for home implies

$$\begin{aligned} &\frac{1}{\tilde{\sigma}-1}\left(\frac{\tilde{\sigma}-1}{\tilde{\sigma}}\right)^{\tilde{\sigma}} (P^\sigma Q)^{\frac{\tilde{\sigma}-1}{\sigma-1}} w^{1-\tilde{\sigma}} \int_{\varphi^*(\tau)} \left[\varphi^{\tilde{\sigma}-1}\varepsilon^{-\tilde{\sigma}}\right] dG - wf\int_{\varphi^*(\tau)} dG \\ &+\Big[\frac{1}{\tilde{\sigma}-1}\left(\frac{\tilde{\sigma}-1}{\tilde{\sigma}}\right)^{\tilde{\sigma}} (P_f^\sigma Q_f)^{\frac{\tilde{\sigma}-1}{\sigma-1}} (\tau_x w)^{1-\tilde{\sigma}} \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})} \left[\varphi^{\tilde{\sigma}-1}\varepsilon_{ex}^{-\tilde{\sigma}}\right] dG - wf_x \int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty} \tau_{fx} dG\Big] = wf_e. \end{aligned} \tag{A.47}$$

A similar equation holds for the foreign economy.

$$\begin{aligned} &\frac{1}{\tilde{\sigma_f}-1}\left(\frac{\tilde{\sigma_f}-1}{\tilde{\sigma_f}}\right)^{\tilde{\sigma_f}} (P_f^\sigma Q_f)^{\frac{\tilde{\sigma_f}-1}{\sigma-1}} w_f^{1-\tilde{\sigma_f}} \int_{\varphi_f^*(\tau)} \left[\varphi^{\tilde{\sigma_f}-1}\varepsilon^{-\tilde{\sigma_f}}\right] dG_f - w_f f\int_{\varphi_f^*(\tau)} dG_f \\ &\quad+\Big[\frac{1}{\tilde{\sigma_f}-1}\left(\frac{\tilde{\sigma_f}-1}{\tilde{\sigma_f}}\right)^{\tilde{\sigma_f}} (P^\sigma Q)^{\frac{\tilde{\sigma_f}-1}{\sigma-1}} \left(\tau_x w_f\right)^{1-\tilde{\sigma_f}} \int_{\varphi_{xf}^*(\varepsilon_{ex},\tau_{fx})} \left[\varphi^{\tilde{\sigma_f}-1}\varepsilon_{ex}^{-\tilde{\sigma_f}}\right] dG_f \\ &\qquad - w_f f_x \int_{\varphi_{xf}^*(\tau_{ex},\tau_{fx})}^{\infty} \tau_{fx} dG_f\Big] = w_f f_e. \end{aligned} \tag{A.48}$$

Measure M and M_f Conditional on entry, the expected per-period profit includes the profit from both domestic production and exporting, where the average profits for domestic and foreign sales are given by

$$E\pi = E\left[\frac{1}{\tilde{\sigma}-1}\frac{wq}{\varphi} - wf\right], \qquad E_x\pi_x = E_x\left[\frac{1}{\tilde{\sigma}-1}\frac{\tau_x w q_x}{\varphi} - w\tau_{fx}f_x\right].$$

Free entry implies

$$E\left[\frac{1}{\tilde{\sigma}-1}\frac{wq}{\varphi} - wf\right] + \omega_x E_x\left[\frac{1}{\tilde{\sigma}-1}\frac{\tau_x w q_x}{\varphi} - w\tau_{fx}f_x\right] = \frac{wf_e}{\omega_e}.$$

The labor market clearing condition implies

$$L = M\left(E\frac{q}{\varphi} + f\right) + M\omega_x\left(E_x\frac{\tau_x q_x}{\varphi} + f_x\right) + M_e f_e.$$

Hence, we can write M_e as

$$M_e = \frac{L}{\tilde{\sigma} f_e + \tilde{\sigma}\omega_e f + \omega_x\omega_e f_x\left[(\tilde{\sigma}-1)E_x\tau_{fx} + 1\right]}. \tag{A.49}$$

A similar equation holds for the Foreign economy.

$$M_{ef} = \frac{L_f}{\tilde{\sigma}_f f_e + \tilde{\sigma}_f\omega_{ef} + \omega_{xf}\omega_{ef} f_x\left[(\tilde{\sigma}_f-1)E_{xf}\tau_{fx} + 1\right]}. \tag{A.50}$$

Aggregate price level

$$\begin{aligned} P^{1-\sigma} = \Bigg[& \left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}} (P^{\sigma}Q)^{\beta\frac{1-\tilde{\sigma}}{1-\beta}} M w^{\frac{1-\tilde{\sigma}}{1-\beta}} \frac{\int_{\varphi^*(\varepsilon)} \left(\frac{\varphi}{\varepsilon}\right)^{\frac{\tilde{\sigma}-1}{1-\beta}} dG}{\int_{\varphi^*(\varepsilon)} dG} \\ & + \left(\frac{\tilde{\sigma}_f}{\tilde{\sigma}_f-1}\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} (P^{\sigma}Q)^{\beta_f\frac{1-\tilde{\sigma}_f}{1-\beta_f}} M_f(\tau_x w_f)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} \frac{\int_{\varphi^*_{xf}(\varepsilon_{ex},\tau_{fx})}^{\infty} \left(\frac{\varphi}{\varepsilon_{ex}}\right)^{\frac{\tilde{\sigma}_f-1}{1-\beta_f}} dG_f}{\int_{\varphi^*_f(\varepsilon)}^{\infty} dG_f} \Bigg] \end{aligned} \tag{A.51}$$

$$\begin{aligned} P_f^{1-\sigma} = \Bigg[& \left(\frac{\tilde{\sigma}_f}{\tilde{\sigma}_f-1}\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} \left(P_f^{\sigma}Q_f\right)^{\beta_f\frac{1-\tilde{\sigma}_f}{1-\beta_f}} M_f w_f^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} \frac{\int_{\varphi^*_f(\varepsilon)} \left(\frac{\varphi}{\varepsilon}\right)^{\frac{\tilde{\sigma}_f-1}{1-\beta_f}} dG_f}{\int_{\varphi^*_f(\varepsilon)} dG_f} \\ & + \left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}} \left(P_f^{\sigma}Q_f\right)^{\beta\frac{1-\tilde{\sigma}}{1-\beta}} M(\tau_x w)^{\frac{1-\tilde{\sigma}}{1-\beta}} \frac{\int_{\varphi^*_x(\varepsilon_{ex},\tau_{fx})}^{\infty} \left(\frac{\varphi}{\varepsilon_{ex}}\right)^{\frac{\tilde{\sigma}-1}{1-\beta}} dG}{\int_{\varphi^*(\varepsilon)}^{\infty} dG} \Bigg] \end{aligned} \tag{A.52}$$

Summary of equilibrium conditions The equilibrium consists of $(P, P_f, M, M_f, Q, Q_f, w_f)$ with $w = 1$ as normalization. In addition to the free entry conditions (A.47) and (A.48), the pricing equations (A.51) and (A.52), and measure of firms (A.49) and (A.50), there is one balanced trade condition

$$\left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}}\left(P_f^{\sigma}Q_f\right)^{\frac{\tilde{\sigma}}{\sigma}}M\tau_x^{\frac{1-\tilde{\sigma}}{1-\beta}}\frac{\int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}\left(\frac{w\tau_x\varepsilon_{ex}}{\varphi}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}}dG}{\int_{\varphi^*(\varepsilon)}dG}$$
$$=\left(\frac{\tilde{\sigma}_f}{\tilde{\sigma}_f-1}\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}}\left(P^{\sigma}Q\right)^{\frac{\tilde{\sigma}_f}{\sigma}}w_f^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}}\tau_x^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}}M_f\frac{\int_{\varphi_{xf}^*(\varepsilon_{ex},\tau_{fx})}\left(\frac{w_f\tau_x\varepsilon_{ex}}{\varphi}\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}}dG_f}{\int_{\varphi_f^*(\varepsilon)}dG_f},$$

along with the associated cutoffs given above.

K.1 Welfare with Endogenous Wedges

Proposition 4. *The change in welfare associated with an iceberg cost shock is*

$$\begin{aligned}d\ln W =&\frac{1}{\gamma_\lambda+\tilde{\sigma}-1}[-d\ln\lambda+d\ln M_e] \\ &+\frac{(\frac{\sigma\gamma_\lambda}{\sigma-1}+\frac{\tilde{\sigma}-1}{\sigma-1}\sigma-1)(\gamma_s-\gamma_\lambda)+(\frac{\tilde{\sigma}-1}{\sigma-1}-1)(\gamma_\lambda+\tilde{\sigma}-1)}{(\gamma_\lambda+\tilde{\sigma}-1)(\gamma_s+\tilde{\sigma}-1)}[-d\ln\lambda+d\ln M_e] \\ &+\frac{\frac{\sigma\gamma_\lambda}{\sigma-1}+\tilde{\sigma}-1}{\gamma_s+\tilde{\sigma}-1}\left[(-d\ln\lambda+d\ln S)+d\ln\left(1+\frac{M_e f_x\int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right)dG}{L}\right)\right]\end{aligned} \quad (A.53)$$

where $\tilde{\sigma}=\sigma/(1-\beta+\sigma\beta)$.

1. *With homogenous productivity, and a distortion that positively depends on a firm's sales with an elasticity of* β *and a Pareto-distributed distortion* $1/\varepsilon$ *with parameter* θ*:*

$$dlnW=\frac{\sigma}{\sigma-1}\left[d\ln S-d\ln\lambda\right],$$

which is the same expression as the case without endogenous wedges.

2. *With Pareto-distributed productivity with parameter* θ*, and a distortion that positively depends on a firm's sales with an elasticity of* β*, and no exogenous distortions, the welfare becomes*

$$d\ln W=\frac{1}{\theta}\Big[-d\ln\lambda+\left(\frac{\sigma}{\sigma-1}\theta-1\right)(-d\ln\lambda+d\ln S)\Big].$$

Under a general distribution, β shows up explicitly in the formula (Eq. A.56). On the one hand, it changes the elasticity by changing σ to an effective elasticity, $\tilde{\sigma} = \sigma/(1-\beta+\sigma\beta) \leq \sigma$ if $\beta \geq 0$. On the other hand, the endogenous wedge also affects the elasticity of γ_λ and γ_s.

Proof. We now prove the general welfare formula under the endogenous wedge.

(1) Let the labor share be

$$S = \frac{(P^\sigma Q)^{\frac{\tilde{\sigma}-1}{\sigma-1}} \int_{\varphi^*(\varepsilon)} \varphi^{\tilde{\sigma}-1}\varepsilon^{-\tilde{\sigma}} dG}{\left[(P^\sigma Q)^{\frac{\tilde{\sigma}-1}{\sigma-1}} \int_{\varphi^*(\varepsilon)} \varphi^{\tilde{\sigma}-1}\varepsilon^{-\tilde{\sigma}} dG + (P_f^\sigma Q_f)^{\frac{\tilde{\sigma}-1}{\sigma-1}} \tau_x^{1-\tilde{\sigma}} \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})} \varphi^{\tilde{\sigma}-1}\varepsilon_{ex}^{-\tilde{\sigma}} dG\right]} \tag{A.54}$$

The labor market clearing condition is

$$\begin{aligned} L &= M\left(E\frac{q}{\varphi} + f\right) + M\omega_x\left(E_x\frac{\tau_x q_x}{\varphi} + f_x\right) + M_e f_e \\ &= M\tilde{\sigma}\left[\frac{f_e}{\omega_e} + f + \omega_x f_x \frac{(\tilde{\sigma}-1)E_x\tau_{fx}+1}{\tilde{\sigma}}\right] \end{aligned}$$

Hence,

$$M = \frac{L}{\tilde{\sigma}\frac{f_e}{\omega_e} + \tilde{\sigma} f + \omega_x f_x\left[(\tilde{\sigma}-1)E_x\tau_{fx}+1\right]}.$$

Combined with the free entry condition A.47, and using the definition of S,

$$\begin{aligned} &\frac{1}{\tilde{\sigma}-1}\left(\frac{\tilde{\sigma}-1}{\tilde{\sigma}}\right)^{\tilde{\sigma}} (P^\sigma Q)^{\frac{\tilde{\sigma}-1}{\sigma-1}} w^{1-\tilde{\sigma}} \int_{\varphi^*(\varepsilon)} \left[\varphi^{\tilde{\sigma}-1}\varepsilon^{-\tilde{\sigma}}\right] dG \\ &+ \frac{1}{\tilde{\sigma}-1}\left(\frac{\tilde{\sigma}-1}{\tilde{\sigma}}\right)^{\tilde{\sigma}} (P_f^\sigma Q_f)^{\frac{\tilde{\sigma}-1}{\sigma-1}} (\tau_x w)^{1-\tilde{\sigma}} \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})} \left[\varphi^{\tilde{\sigma}-1}\varepsilon_{ex}^{-\tilde{\sigma}}\right] dG \\ &= w f_e + w f \int_{\varphi^*(\varepsilon)} dG + w f_x \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty} \tau_{fx} dG \end{aligned}$$

$$\frac{1}{\tilde{\sigma}-1}\left(\frac{\tilde{\sigma}-1}{\tilde{\sigma}}\right)^{\tilde{\sigma}} \frac{(P^\sigma Q)^{\frac{\tilde{\sigma}-1}{\sigma-1}} \int_{\varphi^*(\varepsilon)} \varphi^{\tilde{\sigma}-1}\varepsilon^{-\tilde{\sigma}} dG}{S} = \frac{L}{\tilde{\sigma} M_e}\left[1 + \frac{M_e f_x}{L} \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty} (\tau_{fx}-1)\, dG\right]$$

and log differentiating, we have

$$\frac{\tilde{\sigma}-1}{\sigma-1} d\ln\left(P^{\sigma}Q\right) - \gamma_S d\ln\varphi^* - d\ln S = -d\ln M_e + d\ln\left[1 + \frac{M_e f_x}{L}\int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right) dG\right]$$

(2) Define the total spending E as

$$E = \left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}} \left(P^{\sigma}Q\right)^{\beta\frac{1-\tilde{\sigma}}{1-\beta}+1} Mw^{\frac{1-\tilde{\sigma}}{1-\beta}} \frac{\int_{\varphi^*(\varepsilon)}\left(\frac{\varphi}{\varepsilon}\right)^{\frac{\tilde{\sigma}-1}{1-\beta}} dG}{\int_{\varphi^*(\varepsilon)} dG}$$
$$+ \left(\frac{\tilde{\sigma}_f}{\tilde{\sigma}_f-1}\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} \left(P^{\sigma}Q\right)^{\beta_f\frac{1-\tilde{\sigma}_f}{1-\beta_f}+1} M_f\left(\tau_x w_f\right)^{\frac{1-\tilde{\sigma}_f}{1-\beta_f}} \frac{\int_{\varphi_{xf}^*(\varepsilon_{ex},\tau_{fx})}^{\infty}\left(\frac{\varphi}{\varepsilon_{ex}}\right)^{\frac{\tilde{\sigma}_f-1}{1-\beta_f}} dG_f}{\int_{\varphi_f^*(\varepsilon)}^{\infty} dG_f}$$

hence the sales share is

$$\lambda = \frac{\left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}} \left(P^{\sigma}Q\right)^{\beta\frac{1-\tilde{\sigma}}{1-\beta}+1} Mw^{\frac{1-\tilde{\sigma}}{1-\beta}} \frac{\int_{\varphi^*(\varepsilon)}\left(\frac{\varphi}{\varepsilon}\right)^{\frac{\tilde{\sigma}-1}{1-\beta}} dG}{\int_{\varphi^*(\varepsilon)} dG}}{E} \tag{A.55}$$

Substituting into the price index (A.51),

$$P^{1-\sigma} = \frac{\left(\frac{\tilde{\sigma}}{\tilde{\sigma}-1}\right)^{\frac{1-\tilde{\sigma}}{1-\beta}} \left(P^{\sigma}Q\right)^{\beta\frac{1-\tilde{\sigma}}{1-\beta}} Mw^{\frac{1-\tilde{\sigma}}{1-\beta}} \frac{\int_{\varphi^*(\varepsilon)}\left(\frac{\varphi}{\varepsilon}\right)^{\frac{\tilde{\sigma}-1}{1-\beta}} dG\left(\varphi,\varepsilon,\varepsilon_{ex},\tau_{fx}\right)}{\int_{\varphi^*(\varepsilon)} dG\left(\varphi,\varepsilon,\varepsilon_{ex},\tau_{fx}\right)}}{\lambda}$$

and log differentiating, we have

$$(1-\sigma) d\ln P = \frac{\beta(1-\tilde{\sigma})}{1-\beta} d\ln\left(P^{\sigma}Q\right) + d\ln M_e - \gamma_{\lambda} d\ln\varphi^* - d\ln\lambda$$

where the cutoff if $d\ln\varphi^* = -\frac{1}{\sigma-1} d\ln(P^{\sigma}Q)$ as before.

(3) Summary of three equations

$$\frac{\tilde{\sigma}-1}{\sigma-1} d\ln\left(P^{\sigma}Q\right) - \gamma_S d\ln\varphi^* - d\ln S = -d\ln M_e + d\ln\left[1 + \frac{M_e f_x}{L}\int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right) dG\right]$$

$$\frac{\beta(\tilde{\sigma}-1)}{1-\beta} d\ln\left(P^{\sigma}Q\right) + (1-\sigma) d\ln P = d\ln M_e - \gamma_\lambda d\ln\varphi^* - d\ln\lambda$$

$$d\ln\varphi^* = -\frac{1}{\sigma-1} d\ln(P^{\sigma}Q)$$

Combining the above three equations, the change in welfare associated with an iceberg cost shock is

$$\begin{aligned} d\ln W =& \frac{1}{\gamma_\lambda+\tilde{\sigma}-1}[-d\ln\lambda + d\ln M_e] \\ &+ \frac{(\frac{\sigma\gamma_\lambda}{\sigma-1}+\frac{\tilde{\sigma}-1}{\sigma-1}\sigma-1)(\gamma_s-\gamma_\lambda)+(\frac{\tilde{\sigma}-1}{\sigma-1}-1)(\gamma_\lambda+\tilde{\sigma}-1)}{(\gamma_\lambda+\tilde{\sigma}-1)(\gamma_s+\tilde{\sigma}-1)}[-d\ln\lambda + d\ln M_e] \\ &+ \frac{\frac{\sigma\gamma_\lambda}{\sigma-1}+\tilde{\sigma}-1}{\gamma_s+\tilde{\sigma}-1}\left[(-d\ln\lambda + d\ln S) + d\ln\left(1+\frac{M_e f_x \int_{\varphi_x^*(\varepsilon_{ex},\tau_{fx})}^{\infty}\left(\tau_{fx}-1\right)dG}{L}\right)\right] \end{aligned} \tag{A.56}$$

where $\tilde{\sigma}=\sigma/(1-\beta+\sigma\beta)$.

If $\beta=0$, $\tilde{\sigma}=\sigma$, and the benchmark result is restored. Otherwise, $\tilde{\sigma}$ includes β.

Special Case I. Recall that $\ln\tau = \beta\ln pq + \ln\varepsilon$. With homogenous productivity and Pareto-distributed domestic distortion $1/\varepsilon$ with parameter θ, the original result is again restored:

$$d\ln W = \frac{\sigma}{\sigma-1}\left[d\ln S - d\ln\lambda\right].$$

Proof: Assume $x=1/\varepsilon$ follows a Pareto distribution, then

$$\frac{(1-\tilde{\sigma})}{1-\sigma} d\ln\left(P^{\sigma}Q\right) = d\ln S - d\ln M_e - d\ln\int_{x*} x^{\tilde{\sigma}} x^{-\theta-1} dx$$

$$\frac{\beta(\tilde{\sigma}-1)}{1-\beta} d\ln\left(P^{\sigma}Q\right) + (1-\sigma) d\ln P = -d\ln\lambda + d\ln M_e + d\ln\int_{x*} x^{\frac{\tilde{\sigma}-1}{1-\beta}} x^{-\theta-1} dx$$

Plugging in the cutoff:

$$\frac{(1-\beta)\theta}{\sigma} d\ln\left(P^{\sigma}Q\right) = d\ln S - d\ln M_e$$

$$\left(\frac{\sigma-1}{\sigma} - \frac{(1-\beta)\theta}{\sigma}\right) d\ln\left(P^{\sigma}Q\right) + (1-\sigma) d\ln P = -d\ln\lambda + d\ln M_e.$$

Thus, we have

$$d\ln P = -\frac{1}{\theta(1-\beta)}\Big[(-d\ln\lambda + d\ln M_e) + \left(\frac{\theta(1-\beta)}{\sigma-1} - 1\right)(-d\ln\lambda + d\ln S)\Big]$$

$$d\ln Q = \frac{\sigma}{\sigma-1}\left[d\ln S - d\ln\lambda\right]$$

□

Special Case II. The case with φ and β, but no other type of ε, and a Pareto distributed productivity with parameter θ, welfare becomes

$$d\ln W = \frac{1}{\theta}\Big[-d\ln\lambda + \left(\frac{\sigma}{\sigma-1}\theta - 1\right)(-d\ln\lambda + d\ln S)\Big]$$

Proof: From the definition of S in A.54, the integral in the numerator become $\int_{\varphi*}\varphi^{\tilde{\sigma}-1}\varphi^{-\theta-1}d\varphi$, and for λ in A.55, it becomes $\int_{\varphi*}\varphi^{\frac{\tilde{\sigma}-1}{1-\beta}}\varphi^{-\theta-1}d\varphi$. Thus:

$$\gamma_S = \theta - (\tilde{\sigma}-1), \quad \gamma_\lambda = \theta - \tilde{\sigma} + \frac{\tilde{\sigma}}{\sigma}.$$

Plug into the three equations:

$$\frac{\tilde{\sigma}-1}{\sigma-1}d\ln(P^\sigma Q) - \gamma_S d\ln\varphi^* - d\ln S = -d\ln M_e$$

$$\frac{\beta(\tilde{\sigma}-1)}{1-\beta}d\ln(P^\sigma Q) + (1-\sigma)d\ln P = -d\ln\lambda - \gamma_\lambda d\ln\varphi^* + d\ln M_e$$

$$d\ln\varphi^* = -\frac{1}{\sigma-1}d\ln(P^\sigma Q)$$

We have:

$$d\ln P = -\frac{1}{\theta}\Big[(-d\ln\lambda + d\ln M_e) + \left(\frac{\theta}{\sigma-1} - 1\right)(-d\ln\lambda + d\ln S)\Big]$$

$$d\ln PQ = (-d\ln\lambda + d\ln S)$$

$$d\ln Q = \frac{1}{\theta}\Big[(-d\ln\lambda + d\ln M_e) + \left(\frac{\sigma}{\sigma-1}\theta - 1\right)(-d\ln\lambda + d\ln S)\Big]$$

Table A-10: Endogenous Wedge

	Endogenous wedge $\beta = 0.2$			Benchmark
	Only endo. wedge (recali)	Bench para.	Endo. & exog. wedge (recali)	
Parameters for distribution				
Std. productivity σ_{φ}	1.44	1.31	1.33	1.36
Std. distortion on home sales σ_{τ}		1.05	1.15	1.13
Corr(prod., domestic distortion) $\rho_{\varphi,\tau}$		0.89	0.75	0.90
Std. distortion on export sales $\sigma_{\tau_{ex}}$		0.95	0.99	1.01
Corr(prod., foreign sale distortion) $\rho_{\varphi,\tau_{ex}}$		0.65	0.25	0.62
Corr(τ, τ_{ex}) $\rho_{\tau,\tau_{ex}}$		0.68	0.40	0.64
Std. distortion on export fixed cost $\sigma_{\tau_{fx}}$		0.65	0.55	0.62
Corr(prod., exporting fixed cost) $\rho_{\varphi,\tau_{fx}}$		0.30	0.30	0.30
Corr(τ, τ_{fx}) $\rho_{\tau,\tau_{fx}}$		−0.10	−0.20	−0.10
Corr(τ_{ex}, τ_{fx}) $\rho_{\tau_{ex},\tau_{fx}}$		0.00	−0.25	0.01
Key momentss				
Std. TFPQ	1.29	1.23	1.26	1.32
Std. TFPR	0.43	0.93	0.91	0.95
Corr (TFPR, TFPQ)	0.98	0.95	0.89	0.92
Export intensity	0.24	0.40	0.42	0.47
Std. export intensity	0.00	0.23	0.30	0.33
Among Exporters				
Std. TFPQ.	0.77	1.21	1.25	1.34
Std. TFPR.	0.27	0.85	0.80	0.87
Corr (TFPR, TFPQ)	0.998	0.95	0.91	0.89
Corr (export intensity, TFPQ)	*n.a.*	0.20	−0.18	−0.17
Corr (export intensity, TFPR)	*n.a.*	0.27	−0.08	−0.03
Among Non-Exporters				
Std. TFPQ.	0.82	1.24	1.31	1.31
Std. TFPR	0.34	0.96	0.89	0.98
Corr. (TFPR, TFPQ)	0.997	0.96	0.92	0.93
Trade correlations				
Corr (export intensity, TFPQ)	0.78	0.02	0.01	−0.01
Corr (export intensity, TFPR)	0.66	−0.03	−0.09	−0.03
Corr (export participation, TFPQ)	0.78	−0.10	0.10	0.06
Corr (export participation, TFPR)	0.66	−0.21	−0.09	−0.03
Home welfare gains from trade				
Overall	6.52	−0.08	−1.66	−3.68
ACR/MR	16.95	18.85	19.44	11.1
No-distortion	8.46	3.31	1.89	2.60

Note: TFPR and TFPQ are logged. Corr denotes correlation and Std for standard deviation. In all estimations, fraction of firms producing and exporting, import share, and relative GDP are perfectly matched and not listed in the table. ACR are constructed according to (Eq.A.56). 'Only endo. wedge (recali)' estimates the model with only endogenous wedge. 'Bench para' uses benchmark parameters and $\beta = 0.2$. 'Endo. & exog. wedge (recali)' estimates the model with both endogenous and exogenous wedges.

K.2 Quantitative Results

Table A-10 reports quantitative impact of endogenous wedges with $\beta = 0.2$ and contrast them with our benchmark model under exogenous wedges. To highlight the role of endogenous wedge, we consider three cases. The first case shuts down all exogenous distortions $(\varepsilon, \varepsilon_{ex}, \tau_{fx})$ and keeps only the endogenous ones. We reestimate all the parameters using the relevant moments. The second case includes both endogenous and exogenous wedges and adopts benchmark parameters. The third case reestimates this model with both exogenous and endogenous wedges.

The first column of Table A-10 reports the results with only endogenous wedges. We reestimate all the parameters $(f, f_x, \tau_x, \mu_{\varphi f})$ and the standard deviation of productivity σ_φ. The fraction of firms producing and exporting, import share, and relative GDP are perfectly matched and omitted from the table. With only heterogeneity on productivity, we target only the overall standard deviation of TFPQ but not TFPR moments or cross-group TFPQ distributions.

The results with only endogenous wedges have the counterfactual feature of 1) generating almost perfectly correlated TFPR and TFPQ among exporters and among non-exporters, 0.998 and 0.997 respectively; 2) the selection into exporting market is based solely on productivity, and thus exporters have higher TFPQ and TFPR than non-exporters, as reflected by their correlation with export participation — 0.78 and 0.66, respectively. However, in the data, they are 0.06 and -0.03. Exporters, in particular, have a higher TFPR in the model, contrary to the data.[23] Lastly, 3) the endogenous wedge alone generates less than half of the observed TFPR dispersions. Therefore, even the endogenous wedge distorts the production incentive of highly productive firms and leads to a negative distortion term; this effect is not large enough. The resultant magnitude of distortion is more than half the size of ACR. In contrast, these two terms have similar magnitudes in the benchmark. Hence, with less dispersed TFPR, the endogenous wedge model generates higher overall gain from trade than the benchmark, but it remains lower than without distortions.

Note that these counterfactual features are generic and present also for higher levels of

[23] Apendix L studies a model with endogenous markup as in Edmond, Midrigan, and Xu (2018). The model has a similar counterfactual implication: exporters end up with higher TFPR since they are more productive and charge a higher endogenous markup.

β as long as there are no exogenous distortions. Again, the perfect correlation between $\ln \tau$ ($\ln \tau_{ex}$) and $\ln \varphi$ leads to almost perfect within-group correlations between TFPR and TFPQ and causes the counterfactual selection into the exporting market.

We now add exogenous distortions $(\varepsilon, \varepsilon_{ex}, \tau_{fx})$ to this model with $\beta = 0.2$ and other parameters as the benchmark. See the second column of Table A-10. Adding exogenous distortions helps the model in resolving the aforementioned counterfactual features. The dispersions of TFPR are nearly identical to those in the benchmark. Exogenous distortions also break the selection solely on the basis of productivity φ. Both export participation and export intensity are less correlated with TFPR and TFPQ. Under more dispersed TFPR, the distortion term becomes significantly more negative than when only endogenous wedges are present. As a result, the overall gain from trade decreases from 6.52% to -0.08%.

This model with endogenous and exogenous wedges under benchmark parameters still has some moments that differ from the data. TFPR and TFPQ are still more correlated than the benchmark and the data, for both exporters and non-exporters. The correlation of export participation with TFPR and TFPQ are both too negative relative to the benchmark.

We therefore reestimate this model with endogenous and exogenous wedges in a similar fashion as in the benchmark. See the third column of Table A-10. Given the high correlations of TFPR and TFPQ due to the endogenous wedge, the estimation calls for a larger dispersion of the underlying exogenous wedges $(\varepsilon, \varepsilon_{ex})$ to reduce the correlations. The resultant standard deviations of ε and ε_{ex} are 1.15 and 0.99 respectively, both higher than in the benchmark. The estimation also calls for lower correlations of productivity with ε or ε_{ex} than the benchmark, bringing them down from 0.89 and 0.68 to 0.75 and 0.25. With all the moments close to the benchmark, the magnitude of distortion term is now similar to that of ACR. The consequent gains from trade is therefore negative, about -1.66%, though with the reestimation the result under no distortion is also smaller. Overall, a negative distortion effect offset the gains and leave a small loss from trade.

L Endogenous markup

In this section, we explore a model with endogenous distortion arising from endogenous markup, which has been extensively studied in the standard trade literature. We show that the endogenous markup model runs counter with the data in that exporters in the model face a higher markup and distortion.

Here we build a model with endogenous markup as in Edmond, Midrigan, and Xu (2018). The consumer's problem is the same as before.

Final goods producer Final goods producers are competitive and produce with intermediate goods with a Kimball aggregator

$$\int_{\omega\in\Omega} \gamma\left(\frac{q}{Q}\right) d\omega = 1,$$

where $\gamma(\cdot)$ follows Klenow and Willis (2016) specification as

$$\gamma\left(\frac{q}{Q}\right) = 1 + (\sigma-1)\exp\left(\frac{1}{\varepsilon}\right)\varepsilon^{\frac{\sigma}{\varepsilon}-1}\left[\Gamma\left(\frac{\sigma}{\varepsilon},\frac{1}{\varepsilon}\right) - \Gamma\left(\frac{\sigma}{\varepsilon},\frac{(q/Q)^{\frac{\varepsilon}{\sigma}}}{\varepsilon}\right)\right], \tag{A.57}$$

$\sigma > 1$, $\varepsilon \geq 0$ and $\Gamma(s,x)$ denotes the upper incomplete Gamma function $\Gamma(s,x) = \int_x^\infty t^{s-1}e^{-t}dt$. The demand function for each intermediate good producer is therefore given by

$$p(\omega) = \gamma'\left(\frac{q(\omega)}{Q}\right) PD, \tag{A.58}$$

where D is a demand index, $D = \left[\int_{\omega\in\Omega}\gamma'\left(\frac{q(\omega)}{Q}\right)\frac{q(\omega)}{Q}d\omega\right]^{-1}$.

Intermediate good producer The problem of an intermediate good producer is similar as before except it faces a demand function as in equation (A.58). The firm will choose the price as a markup over the marginal cost,

$$p = \frac{\sigma}{\sigma-(q/Q)^{\frac{\varepsilon}{\sigma}}}\frac{w\tau}{\varphi}.$$

Note that the markup is endogenous and depends on the size of the firm, the higher the quantity a firm sells, the higher the markup it charges. The firm's optimal production and profit increase with φ and decrease with τ. Firms face the same fixed cost and exporting costs as in the Benchmark model, hence there exists a cutoff $\varphi^*(\tau)$, firms produce when $\varphi \geq \varphi^*(\tau)$.

Equilibrium under Endogenous Markup A closed-economy equilibrium consists of aggregate (P, Q, M) that satisfy:

$$M = \frac{\omega_e L}{Q \int_0^{\sigma^{\sigma/\varepsilon}} \int^{\hat{\tau}(\hat{q})} \left[\frac{\sigma}{\sigma - \hat{q}^{\frac{\varepsilon}{\sigma}}} \frac{\hat{q}}{\varphi}\right] g(\varphi(\tau, \hat{q}), \tau) \frac{d\varphi(\tau,\hat{q})}{dq} d\tau d\hat{q}}$$

$$Q \int_0^{\sigma^{\sigma/\varepsilon}} \int^{\hat{\tau}(\hat{q})} \left[\frac{\hat{q}^{\frac{\varepsilon}{\sigma}}}{\sigma - \hat{q}^{\frac{\varepsilon}{\sigma}}} \frac{\hat{q}}{\varphi}\right] g(\varphi(\tau, \hat{q}), \tau) \frac{d\varphi(\tau, \hat{q})}{dq} d\tau d\hat{q} = \omega_e f + f_e$$

$$\frac{M}{\omega_e} \int_0^{\sigma^{\sigma/\varepsilon}} \int^{\hat{\tau}(\hat{q})} \gamma\left(\hat{q}\right) g(\varphi(\tau, \hat{q}), \tau) \frac{d\varphi(\tau, \hat{q})}{dq} d\tau d\hat{q} = 1,$$

where

$$\omega_e = \int_0^{\sigma^{\sigma/\varepsilon}} \int^{\hat{\tau}(\hat{q})} g(\varphi(\tau, \hat{q}), \tau) d\tau d\hat{q}$$

and

$$\gamma'\left(\frac{q}{Q}\right) = \frac{\sigma - 1}{\sigma} \exp\left(\frac{1 - (q/Q)^{\frac{\varepsilon}{\sigma}}}{\varepsilon}\right).$$

The open equilibrium consists of unknowns $(P, Q, M, P_f, Q_f, M_f, w_f)$ that satisfy:

$$\frac{\sigma}{\sigma - \hat{q}_x^{\frac{\varepsilon}{\sigma}}} \frac{w \tau_x \tau}{\varphi} = \gamma'(\hat{q}_x) P_f D_f$$

$$\pi_x = \left[\frac{\hat{q}_x^{\frac{\varepsilon}{\sigma}}}{\sigma - \hat{q}_x^{\frac{\varepsilon}{\sigma}}} \frac{\tau_x \hat{q}_x}{\varphi} Q_f - f_x\right] w,$$

where we get the zero profit cutoff. The free entry condition becomes:

$$\int\int_{\varphi^*(\tau)}\left[\frac{\hat{q}^{\frac{\varepsilon}{\sigma}}}{\sigma-\hat{q}^{\frac{\varepsilon}{\sigma}}}\frac{\hat{q}}{\varphi}Q-f\right]g(\varphi,\tau)d\tau d\varphi + \int\int_{\varphi_x^*(\tau)}\left[\frac{\hat{q}_x^{\frac{\varepsilon}{\sigma}}}{\sigma-\hat{q}_x^{\frac{\varepsilon}{\sigma}}}\frac{\tau_x\hat{q}_x}{\varphi}Q_f-f_x\right]g(\varphi_x,\tau)d\tau d\varphi = f_e \tag{A.59}$$

The labor market clearing condition is:

$$M=\frac{\omega_e L}{\int\int_{\varphi^*(\tau)}\left(\frac{\sigma}{\sigma-\hat{q}^{\frac{\varepsilon}{\sigma}}}\frac{\hat{q}}{\varphi}Q\right)g(\varphi,\tau)d\tau d\varphi+\int\int_{\varphi_x^*(\tau)}\left(\frac{\sigma}{\sigma-\hat{q}_x^{\frac{\varepsilon}{\sigma}}}\frac{\tau_x\hat{q}_x}{\varphi}Q_f\right)g(\varphi,\tau)d\tau d\varphi} \tag{A.60}$$

$$\left[\frac{M}{\omega_e}\int\int_{\varphi^*(\tau)}\gamma\left(\hat{q}\right)g(\varphi,\tau)d\tau d\hat{q}+\frac{M_f}{\omega_{ef}}\int\int_{\varphi_{xf}^*(\tau)}\gamma\left(\hat{q}_{xf}\right)g_f(\varphi,\tau)d\tau d\varphi\right]=1 \tag{A.61}$$

For Foreign,

$$\int\int_{\varphi_f^*(\tau)}\left[\frac{\hat{q}_f^{\frac{\varepsilon}{\sigma}}}{\sigma-\hat{q}_f^{\frac{\varepsilon}{\sigma}}}\frac{\hat{q}_f}{\varphi}Q_f-f\right]g_f(\varphi,\tau)d\tau d\varphi + \int\int_{\varphi_{xf}^*(\tau)}\left[\frac{\hat{q}_{xf}^{\frac{\varepsilon}{\sigma}}}{\sigma-\hat{q}_{xf}^{\frac{\varepsilon}{\sigma}}}\frac{\tau_x\hat{q}_{xf}}{\varphi}Q-f_x\right]g_f(\varphi,\tau)d\tau d\varphi = f_{ef} \tag{A.62}$$

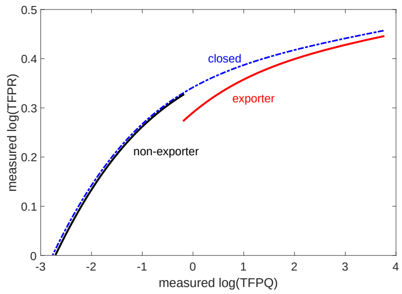
$$M_f=\frac{\omega_e L_f}{\int\int_{\varphi_f(\tau)}\left(\frac{\sigma}{\sigma-\hat{q}_f^{\frac{\varepsilon}{\sigma}}}\frac{\hat{q}}{\varphi}Q_f\right)g_f(\varphi,\tau)d\tau d\varphi+\int\int_{\varphi_{xf}^*(\hat{q})}\left(\frac{\sigma}{\sigma-\hat{q}_{xf}^{\frac{\varepsilon}{\sigma}}}\frac{\tau_x\hat{q}_{xf}}{\varphi}Q\right)g_f(\varphi,\tau)d\tau d\hat{q}} \tag{A.63}$$

$$\left[\frac{M_f}{\omega_{ef}}\int\int_{\varphi_f^*(\tau)}\gamma\left(\hat{q_f}\right)g_f(\varphi,\tau)d\tau d\hat{q}+\frac{M}{\omega_e}\int\int_{\varphi_x^*(\tau)}\gamma\left(\hat{q}_x\right)g(\varphi,\tau)d\tau d\varphi\right]=1 \tag{A.64}$$

Finally, the goods market clearing condition is:

$$\frac{M}{\omega_e}\int\int_{\varphi_x^*(\tau)}\left[\frac{\sigma}{\sigma-\hat{q}^{\frac{\varepsilon}{\sigma}}}\frac{w\hat{q}}{\varphi}Q_f\right]g(\varphi,\tau)d\tau d\varphi=\frac{M_f}{\omega_{ef}}\int\int_{\varphi_{xf}^*(\tau)}\left[\frac{\sigma}{\sigma-\hat{q}_{xf}^{\frac{\varepsilon}{\sigma}}}\frac{w_f\hat{q}_{xf}}{\varphi}Q\right]g_f(\varphi,\tau)d\tau d\varphi \tag{A.65}$$

Figure A-12: Measured TFPR and TFPQ in an Endogenous Markup Model



Notes: TFPQ is measured with $q/(\ell_v + f)$ and TFPR is $pq/(\ell_v + f)$ where ℓ_v is the variable input.

To compare with the benchmark model, we choose ε as 0.08 to match the aggregate marginal product of labor of 1.45 as in Edmond, Midrigan, and Xu (2018), while keeping other parameters the same as in the benchmark. Figure A-12 plots the relationship between the measured $\log(TFPR)$ (which again is ARPL, $pq/(\ell_v + f)$ in the model and f includes exporting fixed cost if firm exports) and the measured $\log(TFPQ)$ (which is $q/(\ell_v + f)$) in the model). First, higher productivity firms produce more and end up with a higher endogenous markup. The measured TFPR is therefore higher. Hence, we observe an upward sloping line for the closed economy. Second, this upward sloping patterns also show up in the open economy. Moreover, exporters are more productive and face a higher wedge. Non-exporters face a more competitive market after opening up and charge a lower markup, the TFPR is smaller. Around the exporting cutoff, exporters face a lower TFPR due to the fixed cost of exporting. Overall, exporters face higher TFPR.

In summary, if the observed wedges are purely driven by markups and they endogenously change with trade, we should see that: 1) exporters on average have higher markups, hence higher—rather than lower—TFPR; and given TFPQ, they should have the same TFPR; 2) measured log (TFPR) and log (VA) will be almost perfectly correlated. These implications are at odds with the regression results, where exporters face lower TFPR. Thus, even in this endogenous markup model, similar exogenous distortions are needed to match the observed dispersion and correlation. This is consistent with Song and Wu (2015) and David and Venkateswaran (2017) that the heterogeneity in markup explains very limited MPK dispersion in China. Moreover, Arkolakis, Costinot, Donaldson, and Rodríguez-Clare (2018) show that the gains from trade in a model with endogenous markup is similar to ACR.