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Misallocation under Trade Liberalization[†]

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This paper formalizes a classic idea that in second-best environments trade can induce welfare losses: incremental income losses from distortions can outweigh trade gains. In a Melitz model with distortionary taxes, we derive sufficient statistics for welfare gains/losses and show departures from the efficient case (Arkolakis, Costinot, and Rodríguez-Clare 2012) can be captured by the gap between an input and output share and domestic extensive margin elasticities. The loss reflects an endogenous selection of more subsidized firms into exporting. Using Chinese manufacturing data in 2005 and model-inferred firm-level distortions, we demonstrate that a sizable negative fiscal externality can potentially offset conventional gains. (*JEL* D22, F14, H25, L60, O19, P31, P33)

The question of how much developing countries benefit from opening up to goods trade is a time-honored 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

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

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 age-old 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, p. 48). 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 as 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.

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)—henceforth, 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 that are marginally able to survive in the domestic market can be driven out as other firms gain market share and drive up costs. In other words, the selection effect that 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: one can infer a negative selection (of more subsidized firms) into exporting if the fall in the domestic input share is larger than the fall in 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) results in a higher subsidy for the domestic market with trade. In other words, trade leads some labor to be allocated to the export sector. In the event that the input share used for producing exports exceeds the export revenue share, exporters are relatively more subsidized, and exports invoke larger subsidies than domestic production. But trade also raises the domestic cutoff. The domestic extensive elasticities determine whether the domestic market also selects more subsidized firms, in which case a reduced tax revenue accrues to the domestic market. Thus, trade causes production to be more subsidized than before, resulting in 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 in 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 homogeneous 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 is relatively larger than that of productivity, and if the wedges and productivity are less correlated. In this case, selection is 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 postgrowth situation versus the pregrowth 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—with heterogeneous firms—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. We operationalize our results in the context of China. We choose China because it is an economy with many distortions[2] and one that experienced an important trade liberalization event

[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 is also widely documented (see Guo et al. 2014 and Bai, Hsieh, and Song 2020). 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 (2019) 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.

in the early 2000s. In our quantitative analysis, we expand upon the basic framework to incorporate additional wedges in the exporting market. We use micro data from Chinese manufacturing and examine the degree of departure from the standard trade models where there are no preexisting domestic distortions. We find that when taking into account distortions in China, the negative fiscal externality can be significant. Calibrating to data in 2005, this externality induces a welfare loss of 15 percent, more than offsetting the conventional ACR gains of 11 percent. Our paper lays emphasis on the potential size of the negative fiscal externality—as a channel that reduces welfare—rather than the overall welfare gain/losses from trade per se.

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: a heavily taxed firm must have high productivity in order 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)—henceforth, HK—Baily, Hulten, and Campbell (1992); Restuccia and Rogerson (2008); and 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 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 2013 and Buera and Oberfield 2020), adoption (Perla, Tonetti, and Waugh 2021 and Sampson 2016), and innovation (Atkeson and Burstein 2010). While these mechanisms in principle work to increase the gains to trade, with its quantitative significance a subject of 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

[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 nonstate sector has been particularly important.

[4] Perla, Tonetti, and Waugh (2021) and Atkeson and Burstein (2010), for instance, find that trade gains are not too different from ACR gains. In Perla, Tonetti, and Waugh (2021), 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.

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—the distortionary effect of firm selection—and benchmark it against the standard effects in canonical trade models. 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]

I. Theoretical Framework

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

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

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

where σ is the elasticity of substitution across intermediate goods, Ω is the endogenous set of goods, and $p(\omega)$ 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.

[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).

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 (greater than one) or subsidy (less than one) on every revenue earned.[6] Once the sunk entry cost is paid, a firm draws its productivity φ and τ independently from a joint 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 a 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

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

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

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

$$\varphi_x^*(\tau) = \frac{\sigma^{\frac{\sigma}{\sigma-1}}}{\sigma - 1}\left(\frac{wf_x\tau_x^{\sigma-1}}{P_f^\sigma Q_f}\right)^{\frac{1}{\sigma-1}} w\tau^{\frac{\sigma}{\sigma-1}}.$$

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 and survive if sufficiently subsidized.

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

[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 extend the production to include capital, i.e., $\varphi k^\alpha \ell^{1-\alpha}$. 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 τ, which appears as an output distortion. This distortion is equivalent to a composite of input distortions at the firm level. In our quantitative exercises, we use an extended model that also incorporates heterogeneous distortions in foreign markets. We use both capital and labor in the data to calculate firms' TFPR.

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

The government's budget is balanced so that the lump-sum transfers are 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 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 distribution 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 measures 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 are $\mu_f(\varphi,\tau)$.

In equilibrium, the Home price index P satisfies

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

Another key equation is the free entry condition:

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

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

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

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

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

Normalizing the Home country wage rate to 1, there are 11 equations, the 2 zero-cutoff productivities for domestic production and exporting (4), the definition of price indexes (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 11 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.

II. Theoretical Comparative Static

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

A. *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

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

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]

In an efficient case without wedges, the transfer T is zero, 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, $T = \int[(\tau_i - 1)/\tau_i]p_i q_i di$. 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 and also the proportion of domestic sales in total sales,

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

[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.

[11] ACR 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.

and S be the *domestic input share*, which is the share of the total variable labor employed by domestic firms that goes toward production for the domestic market,[12]

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

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 ACR and Melitz and Redding (2015)—henceforth, MR—a concept capturing the extensive margins in each market is

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

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

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, yields a general representation of welfare.

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

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

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

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

[12] In equilibrium, the total variable input is a constant share of L. Therefore, we can also define S as the ratio of variable labor in production for the domestic market to L. Regardless of whether we use the total variable input or total L to define S, it always results in the same $d\ln S$.

PROOF:
See Appendix B.

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, $\gamma_\lambda = \gamma_s$, and 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., $\left[\gamma_\lambda/(\sigma - 1)\right]/\left(\gamma_\lambda + \sigma - 1\right) + 1$, 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).

B. *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: (i) whether selling to the foreign market entails more subsidies than selling to the domestic market and (ii) whether there is also a rise in subsidies incurred in the domestic market.

The first force can be determined by comparing $d\ln S$ and $d\ln\lambda$. If exports entail a larger input share than their sales share in the event of more trade, i.e., $d\ln S < d\ln\lambda$, the country is subsidizing more their sales to the foreign markets as compared to the domestic markets. This has a negative impact on the fiscal externality and could result in a reduction in 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 (as a result of trade) decreases output relative to labor in the domestic market. This is indicative of the fact that the surviving firms are the ones that are relatively more subsidized. In this case, tax revenues from domestic sales fall, and this weighs down on the fiscal externality.

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

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

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

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

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), along with the definitions of λ and S, we can express the lump-sum transfer to households as $1 + T = PQ/L = (S/\lambda) \times \big[\big(\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{1-\sigma}dG\big)/\big(\int\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}dG\big)\big]$, which implies

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

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 domestic market selection. 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.,

$$(19)\qquad \frac{wL + T}{L} = \frac{\sigma - 1}{\sigma}\left(\frac{P_xQ_x}{L_{vx}}\frac{L_{vx}}{L_v} + \frac{P_dQ_d}{L_{vd}}\frac{L_{vd}}{L_v}\right),$$

where the equality holds because the variable labor L_v is proportional to the total labor L due to the free entry condition $L_v = [(\sigma - 1)/\sigma]L$ and because 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 $L_v = L_{vx} + L_{vd}$. The equilibrium conditions that expenditure equals income in each market, i.e., $wL_x + T_x = P_xQ_x$ and $wL_d + T_d = P_dQ_d$, are also used here.

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_xQ_x/L_{vx} and P_dQ_d/L_{vd}—and the change in domestic sale per input relative to before trade, i.e., the change of P_dQ_d/L_{vd}. Hence, when trade induces a lower P_xQ_x/L_{vx} than P_dQ_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_dQ_d/L_{vd}, it further lowers tax revenue from domestic production than before.

Turning to Force (i) to infer the subsidies used for foreign versus 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., $\left[(\sigma - 1)/\sigma\right]\left(P_x Q_x / L_{vx}\right)$, whereas the right-hand side is proportional to the sales-input ratio in the domestic market, $\left[(\sigma - 1)/\sigma\right]\left(P_d Q_d / L_{vd}\right)$. 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 $P_x Q_x / L_{vx} < P_d Q_d / L_{vd}$ 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 equations (15) and (18).

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

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

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.

C. *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 homogeneous productivity and Pareto-distributed domestic wedge* $1/\tau$ *with parameter* θ, $d\ln W = [\sigma/(\sigma-1)](d\ln S - d\ln\lambda)$ *and:*

(i) *Moving from a closed economy to an open economy always entails a welfare loss, as* $S < \lambda$ *for any open economy.*[13]

(ii) *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:

See online Appendix B.2.

With homogeneous 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* $\sigma_\tau \geq [(\sigma-1)/\sigma]\rho\sigma_\varphi$, *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.*

PROOF:

See online Appendix B.3.

In the Appendix, we prove that if $\sigma_\tau \geq [(\sigma-1)/\sigma]\rho\sigma_\varphi$, the likelihood ratio order dictates that the cumulative distribution of labor share stochastically dominates the

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

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 $\sigma_\tau \geq \left[(\sigma - 1)/\sigma\right]\rho\sigma_\varphi$ 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 online 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 online 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 the worsening of misallocation of resources.

III. 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 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. However, 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 distortion effect can offset much of the gains to trade commonly understood.

We expand on our benchmark model to make it more quantitatively relevant by incorporating additional heterogeneity in distortions, for instance, allowing firms to face different distortions in the foreign market. Then, we use Chinese firm-level data in the year 2005 to match a broad range of moments with the extended model. Through the welfare decomposition, we show a significant negative distortion term arising from trade as China opens up. Finally, we decompose China's growth in the period of 1998 and 2005 and assess the contribution of trade.[14]

[14] We chose the year 2005 for the benchmark analysis, as this is the year when Chinese exports reached their peak. As shown in Table A-4 of the online Appendix, both the fraction of firms importing and the import share have been increasing until 2005, after which they fell in 2006 and 2007. We consider 2005 as a period when China is

A. *Extended Model*

We expand on the benchmark model in Section I so that firms can also face different distortions in the foreign market. A firm now draws a quadruple $(\varphi, \tau, \tau_{ex}, \tau_{fx})$ from a cumulative distribution $G(\varphi, \tau, \tau_{ex}, \tau_{fx})$, where the two additional wedges include an export wedge τ_{ex} on foreign sales and a wedge on the fixed cost of exporting τ_{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 online Appendix D.

PROPOSITION 3: *The change in welfare associated with an iceberg cost shock is*

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

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

$$(22)\quad d\ln PQ = \frac{\gamma_s - \gamma_\lambda}{\gamma_s + \sigma - 1}(-d\ln\lambda + d\ln M_e) + \left(\frac{\gamma_\lambda + \sigma - 1}{\gamma_s + \sigma - 1}\right)$$

$$\times\left\{(-d\ln\lambda + d\ln S) + d\ln\left[1 + \frac{M_e f_x}{L}\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}(\tau_{fx} - 1)dG\right]\right\}.$$

PROOF:

See online Appendix E.

As it turns out, the welfare decomposition takes on a similar form as in the benchmark model provided in Proposition 2 and also holds for asymmetric countries as

more integrated with the world, while 1998 is a period when China is relatively closed. In addition, the standard deviations of TFPQ and TFPR have been decreasing monotonically. The data moments before 2002 are similar to 1998, while those in 2004 and 2006 are similar to 2005. Hence, we have chosen 2005 and 1998 as two example years. We conduct a robustness check over other years. See online Appendix J.

well as for general distributions of $G(\varphi, \tau, \tau_{ex}, \tau_{fx})$. The additional term reflects the fixed-cost wedge, since the last term becomes zero when $\tau_{fx} = 1$ for all firms, 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 in what follows the relative importance of distortions to output compared to distortions to exporting fixed costs.

B. *Data and Measurement*

The data for Chinese firms come from an annual survey of manufacturing enterprises collected by the Chinese National Bureau of Statistics (NBS China 1998–2007). The dataset includes nonstate firms with sales over ¥5 million (about US$600,000) 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 is that the existence of firm selection requires extrapolating unobserved wedges; the observed dispersion and correlation of some measured wedge and productivity pertain only to operating firms. In other words, since the model embodies an endogenous selection mechanism, even if the underlying correlation were negative, for instance, the export selection mechanism can induce the observed correlation to *become positive*. This is because 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,

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

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 does 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.

C. *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 $\left(\sigma_{\varphi}, \sigma_{\tau}, \sigma_{ex}, \sigma_{fx}\right)$ and six correlations $\left(\rho_{\varphi,\tau}, \rho_{\varphi,\tau_{ex}}, \rho_{\varphi,\tau_{fx}}, \rho_{\tau,\tau_{ex}}, \rho_{\tau,\tau_{fx}}, \rho_{\tau_{ex},\tau_{fx}}\right)$.

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 et al. (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 United States 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.[15]

The remaining 14 parameters, including $\left\{f, f_x, \tau_x, \mu_{f\varphi}\right\}$, the 4 standard deviations, and the 6 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,[16] 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 strictly correspond to φ or τ, respectively. However, this correspondence is roughly true for operating firms if f or f_x were relatively small, as shown in equation (23).[17]

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.[18] Following HK, labor shares are not computed from Chinese data due to the prevalence of distortions. These industry labor shares are constructed using the US NBER-CES Manufacturing Industry Database compiled by Becker, Gray, and Marvakov (2013). 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 $TFPR_{ji} = p_{ji} q_{ji} / \left(k_{ji}^{\alpha_j} \ell_{ji}^{1-\alpha_j}\right)$ and $TFPQ_{ji} \propto \left(p_{ji} q_{ji}\right)^{\sigma/(\sigma-1)} / \left(k_{ji}^{\alpha_j} \ell_{ji}^{1-\alpha_j}\right)$.[19] Both TFPR and TFPQ are measured as

[15] The real GDP data are from PWT 9.0 constructed by Feenstra, Inklaar, and Timmer (2016).

[16] 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 $\left(P^{\sigma} Q\right)^{1/(1-\sigma)} (pq)^{\sigma/(\sigma-1)} / \ell$ using the demand function equation (2).

[17] 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.

[18] We do not 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.

[19] In the benchmark model, we focus on output distortion, which is equivalent to a composite of input distortions at the firm level. When there is a fixed measure of entrants (and hence no f_e), the welfare expressions under the input-wedge model and output-wedge model are identical. The fiscal externality can be expressed by the gap between an input and output share $d\ln S - d\ln\lambda$ and the difference between domestic extensive elasticities of input and output, where input share S is the variable inputs in the domestic market over total inputs. With endogenous

deviations from their 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-6 in the online Appendix.

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.

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 reveal that roughly an average of 85 percent 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 online Appendix K.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 $q/\ell = \varphi\big[1 - f/\ell(\varphi,\tau)\big]$, 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.

entry, we need to specify how the entry cost f_e is affected by the distortions. Given that f_e is paid before the realization of productivities and wedges, we assume f_e is in terms of inputs and not subject to any distortions in our benchmark. For more details, see online Appendix F.

Table 1—Parameterization and Moments

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

Notes: Data moments are for the 2005 Chinese National Bureau of Statistics. TFPR and TFPQ are logged; "corr" denotes correlation, "SD" standard deviation, "ex." export, "ex. intensity" export intensity, and "ex. participation" export participation.

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 $p_x q_x / (pq + p_x q_x) = 1/\left\{1 + \left[P^\sigma Q / \left(P_f^\sigma Q_f\right)\right]\left(\tau_x \tau_{ex}/\tau\right)^{\sigma-1}\right\}$, 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 also inform 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 affects 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 nontargeted moments, such as TFPR and TFPQ among exporters and non-exporters and correlations between export intensity and exporters' TFPR and TFPQ. These nontargeted moments are successfully replicated by our model, as Table 3 shows.

We also assess the model assumption of a log-normal distribution for productivity and wedges. Due to endogenous selection, the underlying distribution cannot be directly extracted using nonparametric methods. Nonetheless, we still leverage the model's estimated fixed cost f to back out (φ_i, τ_i) for each non-exporting firm and compare this backed-out data distribution with the model's distribution of non-exporters. However, we can't use the same approach for exporters since labor used for domestic or 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: $\tau_i = [(\sigma - 1)/\sigma][pq_i/(\ell_i - f)]$ and $\varphi_i = const \times (pq_i)^{\sigma/(\sigma-1)}/(\ell_i - f)$, 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 that in the data 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 and then de-meaned 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-6 in the online Appendix. The standard deviation of $\log(\varphi)$ is 1.36 in the data and 1.32 in the model, while the standard deviation of $\log(\tau)$ is 1.01 in the data and 1.02 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.

D. *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 percent according to our model. By contrast, the ACR/MR formula, $\left[1/(\gamma_\lambda + \sigma - 1)\right]\left(-d\ln\lambda + d\ln M_e\right)$, predicts a welfare gain of about 11 percent. The loss from trade comes from the large and negative distortion term showing up in China, amounting to -15 percent.

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 $\left[(\gamma_\lambda + \sigma - 1)/(\gamma_s + \sigma - 1)\right]\left(d\ln S - d\ln\lambda\right)$ is about -13 percent. The first term, which depends on $\gamma_s - \gamma_\lambda$, contributes only -1 percent, while the terms reflecting the wedges on fixed exporting cost are negligible at 0.03 percent.

The welfare changes considered entail significant changes in trade costs as the economy moves from an open to a closed economy. But the welfare formula (21) is more accurate for small variations in trade cost, and for this reason, 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 computes γ_s and γ_λ using the domestic cutoffs at the open equilibrium and $d\ln M_e$ as the difference in M_e between the open and closed economy. The same applies to $d\ln\lambda$ and $d\ln S$. This method generates an ACR/MR term of 11.1 percent and a distortion term of -15.01 percent. The sum of the two values is -3.91 percent, which is about 0.23 percent lower than the welfare difference calculated directly using the open and closed equilibrium. The direct method is relatively easy to implement but entails 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.[20] Given

[20] 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	−13.52
Term 3 (related to τ_{fx})	0.03	0.03

Notes: All numbers are in percent. Welfare decomposition is conducted according to Proposition 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 $\left[(\gamma_s - \gamma_\lambda)/(\gamma_s + \sigma - 1)\right](-d\ln\lambda + d\ln M_e)$. Term 2 in $d\ln PQ$ is given by $\left[(\gamma_\lambda + \sigma - 1)/(\gamma_s + \sigma - 1)\right](d\ln S - d\ln\lambda)$. And Term 3 related to fixed exporting cost is given by $\left[(\gamma_\lambda + \sigma - 1)/(\gamma_s + \sigma - 1)\right] d\ln\left[1 + (M_e f_x/L)\int_{\varphi_x^*(\tau_{ex},\tau_{fx})}^{\infty}(\tau_{fx} - 1)dG\right]$.

the small changes in iceberg cost, the decomposition holds precisely. The resulting sum of ACR/MR term is 11.23 percent, and the distortion is 14.91 percent. 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 percent, 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 percent. See online Appendix K.1 for details.

E. *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.

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 percent relative to the benchmark of 3.68 percent. However, the country still suffers a loss from trade, and the distortion term is still highly negative, about -15 percent. 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 benchmark 0.98 to 0.11) and exporters (from benchmark 0.87 to 0.03) changes dramatically; the overall welfare gain from trade becomes positive, 2.58 percent, close to the efficient case gains of 2.60 percent. 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 IIIB. 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 can 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 contribute little to fiscal externality and the overall welfare.

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 online 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 percent, compared to -3.68 percent in the benchmark. However, the distortion term is still large and negative, about -12 percent, comparable to the benchmark value -15 percent.

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

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 (percent)								
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	−6.20
Key moments								
SD TFPQ	1.32	1.32	1.30	0.84	0.84	1.32	1.33	1.36
SD 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
SD export intensity	0.38	0.33	0.31	0	0	0.33	0	0.28
Among exporters								
SD TFPQ	1.25	1.33	1.26	0.63	0.55	1.26	1.33	1.25
SD 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	0.89	0.97	0.87
Among non-exporters								
SD TFPQ	1.34	1.31	1.29	0.55	0.52	1.30	1.33	1.40
SD 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	0.49	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	0.002	0.49	0.51	0.05	−0.31	−0.05

Notes: TFPR and TFPQ are logged; "corr" denotes correlation, "SD" standard deviation, "intensity" export intensity, and "part." 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 $\left(\tau, \tau_{ex}, \tau_{fx}\right)$. 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 online Appendix. ACR and Distortion in the welfare decomposition are constructed according to equation (21).

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 percent, while the negative impact of distortion is less severe, at around −7 percent. Although the ACR gain remains around 11 percent 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 online Appendix. The more negative MR term drives down the overall ACR/MR term to 7.7 percent, which is smaller than the benchmark number.

Other Sources 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.[21] Unlike export wedges, these differential costs operate akin to differential productivities but do not cause resource misallocation. Hence, production for export faces no distortions in this model. See online Appendix H and Table A-2 in the online Appendix for model details.

Although the hetero-trade-costs model appears to be as rich as the benchmark model at first glance, it is harder to match the data than our benchmark regarding the large variability in TFPR among exporters and the negative correlation between TFPR and trade in the data. In the hetero-trade-costs model, one way to generate a large dispersion in TFPR is to increase the standard deviation of heterogeneous trade costs. However, doing so leads to a positive correlation between TFPR and export, which contradicts the data. This happens because firms' exporting productivity rises when trade costs are low, resulting in higher levels of TFPR, export participation, and intensity.

An alternative way is to have a large dispersion in domestic wedges, along with a strong positive correlation between domestic wedges and trade costs. This begets a highly dispersed TFPR and a negative correlation between TFPR (when domestic wedge τ is low) and export participation (when export costs are low). Nevertheless, the approach has two limitations: a very positively correlated export intensity and TFPR, and an implied relationship where heavily subsidized domestic firms are more technologically advanced in exporting. The latter seems rather ad hoc, as compared to the equilibrium in our benchmark model, where highly subsidized firms export more because they receive more subsidies, not because they have better technology.

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 0.02, about five times higher than the benchmark distance to the data, 0.004.

Table 3 reports the gains from trade and welfare decompositions in the hetero-trade-costs model. The gain from trade is 5.54 percent, the ACR/MR term is approximately 11 percent, and the distortion term is -6.2 percent. 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 brings about fewer distortions and a less negative distortion term—given that there are no distortions in

[21] 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.

production within the exporting market. But note that the fiscal externality remains negative as the overall domestic production is taxed. The reason is that estimated productivities are more dispersed than wedges and highly positively correlated with wedges, as shown in Table A-2 in the online 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 into exports is driven by the heterogeneous variable and fixed trade costs. All other sources of heterogeneity that may affect the dispersion of TFPR and its correlation with trade would affect the estimation of the underlying distribution of firms' wedges, hence affecting welfare gains.

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 HK and assume that the labor intensity of the US four-digit industry is undistorted. 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 four-digit industries. Nonetheless, it is possible that exporters possess different technologies within the four-digit sectors, which we are unable to distinguish.

The case of processing trade is another situation wherein Chinese exporters end up with different TFPRs compared to 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: in 2005, only 60 percent of the exporters were matched with the custom data, resulting in a loss of 40 percent of exporter information. Second, among the matched exporters, approximately 73 percent 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.

Lastly, we do not consider heterogeneities in industry-level distortions. The welfare loss or gain from trade with industry-level distortions could be different from our benchmark model. In general, to uncover the industry-level distortions, we need a comprehensive model of trade in sector levels, Heckscher-Ohlin or Ricardian models, with sectoral demand and supply parameters, to separate sectoral-level aggregates from sector-level distortions. This is an important topic for future research.

F. *Decomposing China's Growth from 1998 to 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 percent. 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 only reductions in iceberg trade cost, GDP rises by a mere 6 percent compared to the observed 57 percent.

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 are 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 their export intensity. The overall dispersion of TFPR is about 20 percent 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 percent, 19 percent, and 9 percent 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 percent higher than that in 1998, reflecting improvements in technology and factor accumulation over time.

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 their 2005 level.

Table 5 indicates that an increase in technology and inputs alone would result in a 55 percent increase in GDP. Reducing trade costs independently would also increase GDP by 6 percent, and changing the joint distribution of distortion and productivity to that of 2005 would result in a further 5 percent increase in GDP.[22]

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

Table 4—China Growth Analysis

	1998	2005
Panel A. Parameters		
Fixed cost f	0.03	0.07
Fixed export cost f_x	0.05	0.09
Iceberg cost τ_x	3.83	2.85
Foreign prod. $\mu_{f\varphi}$	1.08	2.47
SD prod. σ_φ	1.59	1.36
SD home dist. σ_τ	1.34	1.13
SD export dist. $\sigma_{\tau_{ex}}$	1.11	1.01
$\rho_{\varphi,\tau}$	0.89	0.90
$\rho_{\varphi,\tau_{ex}}$	0.68	0.62
$\rho_{\tau,\tau_{ex}}$	0.64	0.64
SD export cost $\sigma_{\tau_{fx}}$	0.56	0.62
$\rho_{\varphi,\tau_{fx}}$	0.28	0.30
$\rho_{\tau,\tau_{fx}}$	0.10	−0.10
$\rho_{\tau_{ex},\tau_{fx}}$	0.02	0.01
Home prod. μ_φ	0.57	1.00

	1998		2005 (Bench)	
	Data	Model	Data	Model
Panel B. Targeted moments				
Fraction producing	0.85	0.85	0.85	0.85
Fraction exporting	0.25	0.25	0.30	0.30
Import share	0.16	0.16	0.23	0.23
US GDP to China	2.61	2.60	1.79	1.79
SD TFPQ	1.55	1.53	1.32	1.32
SD TFPR	1.12	1.13	0.94	0.95
SD TFPR, exporter	1.01	1.02	0.88	0.87
corr(TFPR, TFPQ)	0.93	0.92	0.91	0.92
corr(TFPR, TFPQ), ex	0.92	0.92	0.90	0.89
SD export intensity	0.38	0.35	0.38	0.33
corr(ex-part., TFPQ)	0.08	0.09	0.06	0.06
corr(ex-part., TFPR)	−0.01	0.01	−0.03	−0.03
corr(ex-int., TFPQ)	0.04	0.01	0.01	−0.01
corr(ex-int., TFPR)	0.00	0.00	−0.04	−0.03
log GDP relative to 2005	−0.57	−0.57		

Notes: Data moments are constructed using Chinese National Bureau of Statistics. TFPR and TFPQ are logged; "corr" denotes correlation, "SD" standard deviation, "ex" export, "ex-int." export intensity, and "ex-part." export participation.

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 percent 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 percent decrease in GDP in 2005. These two effects offset each other, resulting in a modest 5 percent 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 higher welfare is obtained 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 online Appendix I for details.

It should be noted that despite having more dispersed distortions, the gains from trade in 1998 are still positive. The reason is that the relative dispersion of wedges

Table 5—Decomposition of China's Growth between 1998 and 2005

	Change of real GDP (percent)
Benchmark	57
Counterfactual change from 1998 to 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

to productivity is smaller in 1998, and as Corollary 2 indicates, 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. In 1998, the underlying distribution was highly dispersed in productivity, and despite the lower efficiency of the economy, the negative fiscal externality of opening up was small. But between 1998 and 2005, productivity dispersion fell, and the decrease in domestic distortions was larger 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-7 in online Appendix I depicts distortion terms when there are reductions in trade costs, under both 1998 and 2005 calibration. The results for years prior to 2003 are more similar to the 1998 welfare numbers, whereas the latter years in our sample beget similar results to the 2005 benchmark. As such, rather than negative welfare gains per se, we place more emphasis on the negative fiscal externality effect that can counter welfare gains in the presence of distortions.

Worth mentioning is the comparison with Tombe and Zhu (2019), which is an altogether different approach but also finds small gains to trade. In their model, which features migration across regions and sectors in China, international trade contributes to only 7 percent of productivity growth between 2000 and 2005. This is much smaller than the contribution of direct reforms that lower migration costs or 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 precondition 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. At the same time, this quantitative exercise also ignores other potential channels of gains to trade, such as the procompetition effect of trade, or potential transfers of technology (Ramondo and Rodríguez-Clare 2013), though these effects may still be quantitatively small. At least from the perspective of 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.

IV. 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 sizable 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 factor- and sector-level distortions and distortions that 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.

Appendix 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

$$p(\varphi,\tau) = \frac{\sigma}{\sigma-1}\frac{w\tau}{\varphi} \tag{A1}$$

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

Let $\mu(\varphi,\tau)$ be the distribution of operating firms $\mu(\varphi,\tau) = g(\varphi,\tau)/\left[\int\int_{\varphi^*(\tau)}^{\infty}g(\varphi,\tau)d\varphi\,d\tau\right] = g(\varphi,\tau)/\omega_e$ if $\varphi \geq \varphi^*(\tau)$, and zero 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 (A1) of the operating firms:

$$P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}M_e\int\int_{\varphi^*(\tau)}\left(\frac{\varphi}{\tau}\right)^{\sigma-1}g(\varphi,\tau)d\varphi\,d\tau. \tag{A2}$$

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

$$\omega_e E\left[\pi(\varphi,\tau)\right] = wf_e, \tag{A3}$$

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

$$L = ME\left[\frac{q}{\varphi} + f\right] + M_e f_e, \tag{A4}$$

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

$$\omega_e M_e = M. \tag{A5}$$

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

$$M_e = \frac{L}{\sigma(f_e + \omega_e f)}. \tag{A6}$$

Open Economy Equilibrium: Optimal prices and cutoff functions are straightforward analogs 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 indexes 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

$$\begin{aligned} &\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1} w^{1-\sigma}\int\int_{\varphi^*(\tau)}^{\infty}(\varphi^{\sigma-1}\tau^{-\sigma}) g(\varphi,\tau) d\varphi\, d\tau \\ &- wf\int\int_{\varphi^*(\tau)}^{\infty} g(\varphi,\tau) d\varphi\, d\tau \\ &+ \left[\frac{P_f Q_f}{\sigma}\left(P_f\frac{\sigma-1}{\sigma}\right)^{\sigma-1}(\tau_x w)^{1-\sigma}\int\int_{\varphi_x^*(\tau)}^{\infty}(\varphi^{\sigma-1}\tau^{-\sigma}) g(\varphi,\tau) d\varphi\, d\tau \right. \\ &\left. \quad - wf_x\int\int_{\varphi_x^*(\tau)}^{\infty} g(\varphi,\tau) d\varphi\, d\tau\right] = wf_e. \end{aligned} \tag{A7}$$

Rewriting this equation,

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

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

$$\text{(A8)}\quad \frac{P_f Q_f}{\sigma}\left(P_f \frac{\sigma-1}{\sigma}\right)^{\sigma-1} w_f^{1-\sigma} \int\int_{\varphi_f^*(\tau)}^{\infty} \left(\varphi^{\sigma-1}\tau^{-\sigma}\right) g_f(\varphi,\tau) d\varphi\, d\tau$$

$$- w_f f \int\int_{\varphi_f^*(\tau)}^{\infty} g_f(\varphi,\tau) d\varphi\, d\tau$$

$$+ \left[\frac{PQ}{\sigma}\left(P\frac{\sigma-1}{\sigma}\right)^{\sigma-1} \left(\tau_x w_f\right)^{1-\sigma} \int\int_{\varphi_{xf}^*(\tau)}^{\infty} \varphi^{\sigma-1}\tau^{-\sigma} g_f(\varphi,\tau) d\varphi\, d\tau\right.$$

$$\left. - w_f f_x \int\int_{\varphi_{xf}^*(\tau)}^{\infty} g_f(\varphi,\tau) d\varphi\, d\tau\right] = w_f f_e.$$

Home and Foreign aggregate prices are

$$\text{(A9)}\quad P^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left[M\int\int_{\varphi^*(\tau)}^{\infty}\left(\frac{w\tau}{\varphi}\right)^{1-\sigma}\mu(\varphi,\tau)d\varphi\, d\tau\right.$$

$$\left. + M_f \int\int_{\varphi_{xf}^*(\tau)}^{\infty}\left(\frac{w_f\tau\tau_x}{\varphi}\right)^{1-\sigma}\mu_f(\varphi,\tau)d\varphi\, d\tau\right],$$

$$\text{(A10)}\quad P_f^{1-\sigma} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left[M_f\int\int_{\varphi_f^*(\tau)}^{\infty}\left(\frac{w_f\tau}{\varphi}\right)^{1-\sigma}\mu_f(\varphi,\tau)d\varphi\, d\tau\right.$$

$$\left. + M \int\int_{\varphi_{x}^*(\tau)}^{\infty}\left(\frac{w\tau\tau_x}{\varphi}\right)^{1-\sigma}\mu(\varphi,\tau)d\varphi\, d\tau\right].$$

Using the free entry and labor market clearing, we have the Home and Foreign analog:

$$\text{(A11)}\quad M_e = \frac{L}{\sigma\left(f_e + \omega_e f + \omega_x\omega_e f_x\right)}.$$

Lastly, the balanced-trade condition requires

$$\text{(A12)}\quad P_f^{\sigma} Q_f M \int\int_{\varphi_x^*(\tau)}^{\infty}\left(\frac{w\tau_x\tau}{\varphi}\right)^{1-\sigma}\mu(\varphi,\tau)d\varphi\, d\tau$$

$$= P^{\sigma} Q M_f \int\int_{\varphi_{xf}^*(\tau)}^{\infty}\left(\frac{w_f\tau_x\tau}{\varphi}\right)^{1-\sigma}\mu_f(\varphi,\tau)d\varphi\, d\tau.$$

Appendix B. 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 the balanced-trade condition:

$$\text{(B1)}\quad \lambda = \frac{\int\int_{\varphi^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau) d\varphi\, d\tau}{\int\int_{\varphi^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau) d\varphi\, d\tau + \frac{P_f^{\sigma} Q_f}{P^{\sigma} Q} \tau_x^{1-\sigma} \int\int_{\varphi_x^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau) d\varphi\, d\tau}.$$

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

$$\text{(B2)}\, S = \frac{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} g(\varphi,\tau) d\varphi\, d\tau}{\int\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} g(\varphi,\tau) d\varphi\, d\tau + \frac{P_f^{\sigma} Q_f}{P^{\sigma} Q} \tau_x^{1-\sigma} \int\int_{\varphi_x^*(\tau)} \varphi^{\sigma-1} \tau^{-\sigma} g(\varphi,\tau) d\varphi\, d\tau}.$$

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

First, we make use of the following equations: the price index (A9) and the balanced-trade condition (A12). We get

$$\text{(B3)}\qquad P^{1-\sigma} = con_p M_e w^{1-\sigma} \left[\int\int_{\varphi^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau) d\varphi\, d\tau \right.$$
$$\left. + \frac{P_f^{\sigma} Q_f}{P^{\sigma} Q} \tau_x^{1-\sigma} \int\int_{\varphi_x^*(\tau)} \left(\frac{\varphi}{\tau}\right)^{\sigma-1} g(\varphi,\tau) d\varphi\, d\tau \right].$$

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:

$$\text{(B4)}\qquad (1-\sigma) d\ln P = d\ln M_e + d\ln \left[\int_{\varphi^*(\tau)} \varphi^{\sigma-1} \tau^{1-\sigma} dG(\varphi,\tau) \right] - d\ln\lambda.$$

Second, use the free entry condition (A7), the labor market condition, and hence the number of firms (A11), to get

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

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:

$$\text{(B5)}\qquad d\ln P^{\sigma}Q + d\ln\left[\int_{\varphi^*(\tau)}\varphi^{\sigma-1}\tau^{-\sigma}dG(\varphi,\tau)\right] - d\ln S = -d\ln M_e.$$

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

$$\text{(B6)}\qquad (1-\sigma)d\ln P = d\ln M_e - d\ln\lambda - \gamma_{\lambda}(\hat{\varphi}^*)d\ln\hat{\varphi}^*,$$

$$\text{(B7)}\qquad d\ln(PQ) = (1-\sigma)d\ln P - d\ln M_e + d\ln S + \gamma_s(\hat{\varphi}^*)d\ln\hat{\varphi}^*.$$

Hence,

$$\text{(B8)}\qquad d\ln Q = -d\ln P + (-d\ln\lambda + d\ln S) + \left[\gamma_s(\hat{\varphi}^*) - \gamma_{\lambda}(\hat{\varphi}^*)\right]d\ln\hat{\varphi}^*,$$

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

$$\text{(B9)}\qquad d\ln\hat{\varphi}^* = -d\ln P - \frac{1}{\sigma-1}d\ln(PQ).$$

Solving equations (B6)–(B9) gives Proposition 2:

$$\text{(B10)}\quad d\ln W = \underbrace{\frac{1}{\gamma_{\lambda}+\sigma-1}(-d\ln\lambda + d\ln M_e)}_{(ACR/MR)} + \underbrace{\left[\frac{\gamma_{\lambda}/(\sigma-1)}{\gamma_{\lambda}+\sigma-1}+1\right]d\ln PQ}_{(distortions)},$$

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

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

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