Barriers to Firm Growth in Open Economies*

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Abstract

Studies measuring barriers to firm growth assume economies are closed, ignoring information on firm exports. We argue that information on exports is key to interpreting data and improving the accuracy of model predictions. To show this, we develop a dynamic model with export and domestic barriers. We show theoretically that the closed economy model underestimates barriers and amplifies counterfactuals. By calibrating the model to a set of European countries, we find that the quantitative difference is significant: for example, the closed economy model fails to see that Italian firms are very efficient exporters but poor innovators, and instead concludes that they are mediocre innovators. In terms of predictions, the closed economy model delivers an elasticity of welfare to innovation costs between 31 and 64 percent larger than the open economy model.

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1 Introduction

A major concern in macroeconomics is how different institutions affect firm growth. One way to identify their effects is to focus on the size distribution of firms: in models with endogenous firm sizes, the relevant barriers to growth can be extracted by matching the model's distribution with its empirical counterpart.[1] Typically, however, these studies assume the economy is closed. Taking a different approach, we claim that information on exports adds an important dimension to the discussion beyond what firm size tells us, and this dimension should not be overlooked. In particular, this information helps in interpreting the data and improving policy recommendations.

First, adding an export decision allows us to distinguish between domestic and foreign barriers. The interaction between these determines the direct effect of a given policy (for example, when domestic barriers increase, firms shift their focus towards exports, reducing the aggregate consequences of the increase). Second, the existence of the export market changes the behavior of firms even if they do not export, as the possibility of exporting in the future could affect today's growth decisions. Thus, trade barriers affect both exporters and non-exporters. Although these channels and implications seem intuitive, our contribution is to present a clear characterization of the mechanisms and show their quantitative relevance.

Our model is a continuous time version of Melitz (2003) with endogenous productivities. Firms innovate to increase their productivities (and hence their size), as in Atkeson and Burstein (2010). They become exporters by incurring a sunk cost and die at a constant rate.

In equilibrium, firms are born as non-exporters, grow by innovating, and export after reaching a productivity threshold. The size of the market determines the gains from innovating: the larger the market size, the larger the gain and the greater the innovation. Thus, the model generates a positive relationship between size and productivity. Since higher trade costs prevent access to additional markets, they reduce the incentives to innovate. As a result, because firm productivity and firm size are directly related, a country may have, on average, smaller (less productive) firms because of high innovation costs, high trade costs, or both.

Exporters grow at a constant rate. Acemoglu and Cao (2010) and Luttmer (2007, 2010) find similar

[1] See the literature following Restuccia and Rogerson (2008) and Hsieh and Klenow (2009).

results in the closed economy. As in Gabaix (2011), this implies that the upper tail of the size distribution of firms follows a Pareto distribution. Non-exporters grow at a rate that is increasing in firm size and equals the growth rate of exporters at the export threshold. Intuitively, the closer non-exporters are to becoming exporters, the higher the probability they will succeed in doing so, and the greater the returns to innovation.

We show analytically two dimensions where the closed economy assumption matters. First, in the closed economy the estimates of innovation costs are biased downwards and this bias differs greatly across countries, potentially altering the open economy ranking. The downward bias of the estimates exists because trade increases the incentives to innovate, so to match the same target, the costs must be higher in the open economy. We decompose the bias into two components: a static component related to the profits from exporting and a dynamic component related to the firm growth rates.

Second, the closed economy overpredicts the effects of changing innovation costs on welfare and aggregate productivity, because it fails to take into account that exporters are less exposed to them. In the closed economy, this cost increase reduces innovation, profits, and consequently income and demand, further reducing profits and innovation. In the open economy, firms shift output towards exports, mitigating these effects. We show analytically that higher innovation costs increase the exports-to-sales ratio of exporters, thus milding the aggregate effect down.

A novel result is that lower trade barriers increase incentives for non-exporters to innovate. As firms approach their export threshold, they speed up their growth. Moreover, a reduction in trade barriers also increases the growth rate of non-exporters, who expect to become exporters in the future. This is in line with what Yan-Aw et al. (2011) find empirically by performing counterfactuals on a model that is structurally estimated for Korean data. In their paper, a reduction in export costs increases the R&D of both exporters and non-exporters. This is a theoretical prediction of our framework.

Next, we calibrate the model economy to a set of European countries (Germany, the United Kingdom, Italy, France and Spain) using the European Firms in a Global Economy (EFIGE) database. This database contains detailed, comparable information on manufacturing firms with more than nine employees. Given the sample of countries, our estimates do not capture self-imposed trade barriers such as tariffs; rather, we capture a general type of barrier that is hard to measure, such as distance, language, political, cultural and institutional barriers that prevent the flow of goods across borders. In this sense, our barriers are not necessarily related to trade between countries, but to trade between regions that differ in key aspects that make trade less accessible.

The fact that we solve most of the model analytically makes the task of identifying the parameters relatively easy. For instance, there is a direct (unique) mapping between the slope of the upper tail of the distribution and the growth rates of firms. Hence, the slopes reveal the firm growth rates. Furthermore, the full characterization of firm dynamics provides a direct mapping between growth rates and each of the frictions. Thus, we reverse-engineer the innovation costs that generate such growth rates.

Our results show that the difference between the open and closed assumption is very large, especially regarding counterfactuals: welfare, in units of consumption, reacts by between 31 percent (Italy) and 64 percent (France) more in the closed economy when innovation costs change by 1 percent. The reason is that exporters are less affected by higher domestic innovation costs because they can shift production towards exports.

The difference in the estimation of innovation costs is also significant. First, the better an economy is at exporting, the greater the bias in innovation costs. In Italy, for example, where trade costs are the lowest, innovation costs are 33 percent higher than Germany's. Under the closed economy, this difference narrows to 12 percent. Low export costs mask large domestic distortions. By ignoring data on exports, the closed economy assumes that Italy's barriers to firm growth are not as significant, overlooking the countrys success at exporting.

Second, the closed economy modifies the ranking of countries by innovation costs. In the U.K. under the closed economy, innovation costs are 5 percent lower than Germany's. The open economy estimates this difference to be 2 percent *larger*. The strong ability of U.K. firms to export makes them appear to be more efficient at innovating than the open economy model suggests.

Third, we find results that seem counterintuitive at first glance. In Spain, the open economy shows the highest export costs, which slow down firm growth. Accordingly, one would expect the closed economy to produce high innovation costs to account for the low growth. However, Spains innovation costs, relative to Germany, are similar under the closed and open economies. The reason is that the closed economy assumption is not far off: in Spain, trade costs are quite high, while in Germany a large domestic market reduces the importance of foreign trade.

Our results provide a new interpretation of an old observation: firms start growing faster *before* they become exporters. This led Bernard and Jensen (1999) to conclude that trade barriers are not likely to affect firm productivity because productivity grows before firms export. Our model suggests that trade liberalization boosts the growth of non-exporting firms that hope to export in the future. This result questions the use of non-exporters as a control group during trade liberalization reforms, such as Van Biesebroeck (2005) and De Loecker (2007), since non-exporters are also affected by trade barriers.

We evaluate the performance of the model along a series of non-targeted dimensions. First, both model and data show a similar share of R&D workers (proxy for innovation) to total workers (relative to Germany), except for the U.K.[2] Second, the model successfully captures the differences in wages and value added per worker among countries, accounting for between 54 and 87 percent of the differences in value added per worker.

Our findings are in line with the literature. The strong interdependence of trade and innovation has been found both empirically and theoretically. Caselli and Coleman (2001) find this interdependence empirically in the case of computer adoption in a number of countries, and Bustos (2011) finds it for Argentine firms during a trade liberalization. Caliendo and Rossi-Hansberg (2012) describe a micro-founded mechanism where exporting leads to a reorganization of the firm, hence increasing productivity, and Caliendo et al. (2012) find empirical evidence supporting the mechanism. Trefler (2004) shows that Canadian productivity increased when tariffs dropped, and Rubini (*forthcoming*) shows that a model with innovation can account for this, but models without innovation cannot. Kambourov (2009) finds that reallocation costs (and therefore innovation) reduce the gains from trade. Guadalupe et al. (2012) find important links between innovation, productivity, and exports among multinationals.

Our model is related to Bhattacharya et al. (2011), who use a model with endogenous innovation to identify resource misallocation in a closed economy framework. Impullitti et al. (2013) is related to us in the sense that they develop a continuous time version of Melitz, where firms growth is exogenous, except for the export decision.

Our model abstracts from imports, which is potentially an important channel associated to innova-

[2]Griffith et al. (2006) show that many U.K. firms perform their R&D activities abroad, mainly in the U.S.

tion. Pavcnik (2002), Goldberg et al. (2009) and Goldberg et al. (2010) find strong evidence of this link. This would complement our current results, and leave it as an open question for future research.

The rest of the paper is organized as follows. Section 2 introduces the model. Section 4 describes the data and calibration. Sections 5 and 7 show the quantitative results. Section 6 evaluates the model against non-targeted dimensions. The last section concludes.

2 The Model

The model builds on Melitz (2003). Time is continuous. There are J small open economies that produce a continuum of tradable differentiated goods and one large country, the rest of the world.[3] They are small as in Demidova and Rodrguez-Clare (2009): firms take the demand functions for their products as given, and consumers take the supply functions of foreign goods as given. The supply functions from the rest of the world to each country are the same. The demand functions depend on income and price. All countries face a rest of the world with the same income.

Preferences. An infinitively lived representative consumer in country j has preferences

$$U_j\left(q_i(\omega,t)\right)=\int_0^\infty e^{-\rho t}\ln Q_j(t)dt, \text{ where}$$
$$Q_j(t)=\left[\int_{\Omega_i(t)} q_j(\omega,t)^{\frac{\sigma-1}{\sigma}}d\omega+\int_{\Omega^*(t)} q_j^*(\omega,t)^{\frac{\sigma-1}{\sigma}}d\omega\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where ω is the name of the good, $\Omega_j(t),\Omega^*(t)$ is the set of goods produced in country j and the rest of the world at time t and $q_j(\omega), q_j^*(\omega)$ denote consumption of domestic and imported goods respectively. $\sigma>1$ is the elasticity of substitution between goods. $\rho>0$ is the discount factor.

Technologies. There are incumbent firms in each period that make production, innovation, and exporting decisions. Firms die instantly with an exogenous probability $\delta\in(0,1)$. They are owned by domestic consumers, who receive lump-sum profits. Each firm is a monopolist. Given a productivity

[3]We also assumed a world that contains only the countries in our sample and the results are very similar.

level z and labor services n, the firm producing good ω has technology:[4]

$$y(\omega; z, n) = z^{\frac{1}{\sigma-1}} n$$

A firm can innovate to increase its productivity level z. We choose a functional form for the innovation cost that guarantees that in equilibrium Gibrat's law emerges for exporters (large firms in equilibrium). That is, in equilibrium, the exporter growth rate is independent of firm size. Increasing productivity by $\dot{z}$ costs, in labor units,

$$c_j(z, \dot{z}) = \frac{\kappa_{Ij} z}{2} \left(\frac{\dot{z}}{z}\right)^2$$

where κ_{Ij} is our measure of the innovation cost in country j.

Exporting requires a one-time sunk cost of κ_{xj} units of labor.[5] Once a firm becomes an exporter, it remains so until it dies. Exports are subject to iceberg trade costs. To deliver quantity q an exporter in country j must ship $(1 + \tau_{xj})q, \tau_{xj} \geq 0$.

New firms can enter anytime with $z = 1$ by incurring an entry cost equal to κ_e units of labor that does not vary across countries.

Labor Market Clearing.

$$L_j = \int_{\Omega_j(t)} \left[n_j(\omega, t) + c_j(z(\omega, t), \dot{z}(\omega, t)) + \kappa_{xj} \mathcal{I}_j(\omega, t)\right] d\omega + M_j(t)\kappa_e \quad (2)$$

where $M_j(t)$ is the measure of entrants in country j at time t, L_j is the total number of workers, $c_j(z(\omega, t), \dot{z}(\omega, t))$ is the labor demand for innovation of firm ω, at time t, and $\mathcal{I}$ is the indicator function, which equals 1 if a firm producing good ω becomes an exporter in t; otherwise, it is 0.

Trade Balance.

$$\int_{\Omega_j(t)} \mathcal{I}_j(\omega, t) p_{j,*}(\omega, t) q_{j,*}(\omega, t) d\omega = \int_{\Omega^*(t)} \mathcal{I}^*(\omega, t) p_{*,j}(\omega, t) q_{*,j}(\omega, t) d\omega$$

[4] A preference parameter in the technology follows Atkeson and Burstein (2010) and simplifies the algebra.
[5] In our framework, a per period fixed export cost would be isomorphic.

2.1 Steady State Equilibrium

We solve the model in steady state, and therefore drop the argument t. Let w_j be the wage rate in country j. Let $p_j(\omega)$ be the price of good ω produced in country j. In equilibrium a producer charges the same price independently of destination, so we do not introduce additional notation. Consumers solve

$$\begin{aligned} &\max \ln Q_j \\ s.t. \quad & Q_j = \left[\int_{\Omega_j} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\Omega^*} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}} \\ & \int_{\Omega_j} p(\omega)q(\omega)d\omega + (1+\tau_x^*)\int_{\Omega^*} p(\omega)q(\omega)d\omega = 1 + \int_{\Omega_j} \pi(\omega)d\omega \end{aligned}$$

The last line is the budget constraint. $\pi(\omega)$ is the profits of a firm ω. A * denotes the rest of the world. Let the right-hand side be equal to I_j (for income). The demand of good $\omega \in \Omega_j$ is

$$q_j(\omega; p_j, P_j, I_j, \tau_{xj}^*) = \begin{cases} p_j^{-\sigma} P_j^{\sigma-1} I_j \text{ if } \omega \in \Omega_j \\ \left((1+\tau_{xj}^*)p_j\right)^{-\sigma} P_j^{\sigma-1} I_j \text{ if } \omega \in \Omega^* \end{cases} \tag{3}$$

where P_j is the Dixit-Stiglitz aggregate price in country j:

$$P_j = \left[\int_{\Omega_j} p_j(\omega)^{1-\sigma} d\omega + (1+\tau_x^*)^{1-\sigma}\int_{\Omega^*} p^*(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}} \tag{4}$$

The problem of the firm can be split into a static decision and a dynamic decision. The first involves how much to produce and the price given their current productivity, and the second involves how much to innovate and, for non-exporters, whether to become exporters. The static decision results from solving:

$$\begin{aligned} &\max_{p,p_x,q_d,q_x,n} \quad p_d q_d + (1+\tau_{xj})p_x q_x - w_j n \\ s.t. \quad & q_d + q_x = z(\omega)^{\frac{1}{\sigma-1}} n, \quad q_d = p_d^{-\sigma} P_j^{\sigma-1} I_j, q_x = ((1+\tau_{xj})p_x)^{-\sigma} P^{*\sigma-1} I^* \end{aligned}$$

The solution to these problems is the mark-up rule $p_j(\omega) = p_{jd}(\omega) = p_{jx}(\omega) = \frac{\sigma}{\sigma-1} w_j z(\omega)^{\frac{-1}{\sigma-1}}$. Let $\hat{\pi}_{dj}(P, I, z)$ be the variable profits for a non-exporter (profits before paying innovation or exporting costs) and $\hat{\pi}_{xj}(P, I, z)$ be the same for exporters.

$$\hat{\pi}_{dj}(z(\omega), P_j, I_j) = \sigma^{-1} I_j P_j^{\sigma-1} z(\omega) = \pi_{dj} z(\omega) \tag{5}$$

$$\hat{\pi}_{xj}(z(\omega), P_j, I_j, \tau_{xj}) = \hat{\pi}_d(z(\omega), P_j, I_j) + (1+\tau_{xj})^{1-\sigma} \hat{\pi}_d(z(\omega), P^*, I^*) = \pi_{xj} z(\omega) \tag{6}$$

In what follows we drop out the name of the good ω, since all that matters for profits is z.

The Hamilton-Jacobi-Bellman equation for exporters is

$$(\rho + \delta) V_{xj}(z) = \max_{\dot{z}} \left\{ \pi_{xj} z - \frac{w_j \kappa_{Ij} z}{2} \left(\frac{\dot{z}}{z} \right)^2 + V'_{xj}(z) \dot{z} \right\} \tag{7}$$

For non-exporters, the dynamic problem consists of determining when to become exporters and how much to innovate[6]. Let z_{xj} be the optimal size at which firms become exporters. Their problem is, for $z \in [1, z_{xj}]$

$$(\rho + \delta) V_{dj}(z) = \max_{\dot{z}} \left\{ \pi_{dj} z - \frac{w_j \kappa_{Ij} z}{2} \left(\frac{\dot{z}}{z} \right)^2 + V'_{dj}(z) \dot{z} \right\} \tag{8}$$

$$s.t. \qquad V'_{dj}(z_{xj}) = V'_{xj}(z_{xj}) \tag{9}$$

$$V_{dj}(z_{xj}) = V_{xj}(z_{xj}) - w_j \kappa_{xj} \tag{10}$$

Equation (9) is the smooth pasting condition. It imposes that the change in value at the point of the switch in status is equal before and after switching. Equation (10) imposes that the value of the firm must be the same before and after switching.

The free entry condition is

$$w_j \kappa_e = V_{dj}(1) \tag{11}$$

[6] It is straightforward to show that a non-exporter will always choose to become an exporter if it survives long enough, since the value of being an exporter net of the fixed export cost eventually exceeds the value of never exporting.

2.2 Characterizing the Steady State

Exporters. The linearity in profits and the functional form of the innovation function guarantee that $V_x(z)$ is homogeneous of degree 1. The solution is the productivity of exporters grows at a constant rate, and is therefore independent of firm size. Thus, Gibrat's law holds. This rate of growth is

$$g_{xj} = (\rho+\delta)\left(1-\sqrt{1-h_{xj}}\right), \qquad h_{xj} = \frac{2\pi_{xj}}{(\rho+\delta)^2 w_j \kappa_{Ij}} \tag{12}$$

This rate is increasing in profits and decreasing in innovation costs.[7] The value function is

$$V_{xj}(z) = w_j \kappa_{Ij} g_{xj} z \tag{13}$$

Non-exporters. The first-order condition to the non-exporter problem is

$$g_{dj}(z) = \frac{V'_{dj}(z)}{w_j \kappa_{Ij}} \tag{14}$$

Introducing the solution in the Bellman equation, we have:

$$(\rho+\delta)V_{dj}(z) = \left(\pi_{dj} + \frac{V'_{dj}(z)^2}{2w_j\kappa_{Ij}}\right) z, \quad \forall z \in [1, z_{xj}] \tag{15}$$

Equation (15) defines a first-order differential equation that pins down the non-exporter's value function (and growth rate). The boundary conditions are given by the value matching and smooth pasting conditions. Together, these imply the following:

$$g_{dj}(z_{xj}) = g_{xj}, \qquad z_{xj} = \frac{(\rho+\delta)\kappa_{xj}}{(\rho+\delta)\kappa_{Ij} g_{xj} - \frac{\pi_{dj}}{w_j} - \frac{\kappa_{Ij}}{2} g_{xj}^2} \tag{16}$$

Equation (15) cannot be solved in closed form. However, we can characterize an implicit solution for the non-exporter's growth rate.[8] Proposition 1 shows how trade barriers affect the non-exporting sector.

[7] There is another, larger, growth rate that satisfies the firm's first order condition: $\tilde{g}_{xj} = (\rho+\delta)\left(1+\sqrt{1-h_{xj}}\right)$. However, this growth rate generates losses every period and cannot be an equilibrium.

[8] See footnote 10 for more details on the implicit solution.

Proposition 1 *The non-exporter growth rate is (i) increasing in z, (ii) decreasing in τ_{xj} and κ_{xj} and (iii) weakly smaller than the exporter growth rate.*

Proof: We omit the country subindices for the proof. Notice that (i) and the previously derived condition that $g_d(z_x) = g_x$ imply (iii). So we only need to prove (i) and (ii). To see (ii), first note that $g_d(z) = \frac{V_d'(z)}{w\kappa_I}$ from the first-order condition. Thus, we can rewrite equation (15) as

$$\sqrt{\kappa_I} g_d(z) = \sqrt{(\rho+\delta)V_d(z)/w - \pi_d/w} \tag{17}$$

The proof works by showing $\partial V_d(z)/\partial \tau_x < 0$ and $\partial V_d(z)/\partial \kappa_x < 0$. Using equation (17), this implies $\partial g_d(z)/\partial \tau_x < 0$ and $\partial g_d(z)/\partial \kappa_x < 0$. The value function is

$$\begin{aligned} V_d(z) = \max_{T(z),g(t)} & \int_0^{T(z)} e^{-(\rho+\delta)t} \left[\pi_d z(t) - \frac{\kappa_I}{2} z(t) g(t)^2\right] dt + \\ & \int_{T(z)}^{\infty} e^{-(\rho+\delta)t} \left[\pi_x z(t) - \frac{\kappa_I}{2} z(t) g(t)^2\right] dt - e^{-(\rho+\delta)T(z)} \kappa_x \\ s.t. \qquad & \dot{z}(t) = z(t)g(t), z(0) = z \end{aligned}$$

Using the envelope theorem shows the result (note that $\partial \pi_x/\partial \tau_x < 0$). To see point (i), insert the first-order condition into the Bellman equation for non-exporters to obtain $(\rho+\delta)w\kappa_I g_d(z) = \left[\pi_d + w\frac{\kappa_I}{2} g_d(z)^2\right] z$. Differentiating both sides and rearranging,

$$\frac{g_d(z)}{(\rho+\delta)g_d(z) - \frac{\pi_d}{w\kappa_I} - \frac{g_d^2(z)}{2}} g_d'(z) = \frac{1}{z} \tag{18}$$

We show $g_d'(z) > 0$ by showing that the denominator in the left-hand side is positive. This denominator is a polynomial, and as such can be written as a function of its roots:

$$(\rho+\delta)g_d(z) - \frac{(1-\tau_\pi)\pi_d}{w(1+\tau_l)\kappa_I} - \frac{g_d^2(z)}{2} = (g_d(z) - g_1)(g_2 - g_d(z))$$

where $g_1 = (\rho+\delta)(1-\sqrt{1-h})$, $g_2 = (\rho+\delta)(1+\sqrt{1-h})$, $h = \frac{2\pi_d}{(\rho+\delta)^2 w\kappa_I}$. This holds if $g_1 < g_d(z) < g_2$. To see this, note that if π_d was replaced by π_x, g_1 would be equal to g_x. In fact, g_1 is the growth rate of a firm that expects to make profits π_d forever, or, in other words, if $\tau_x(\kappa_x) \to \infty$. Since we showed already $\partial g_d(z)/\partial \tau_x < 0$, this implies $g_1 < g_d(z)$ for all $z \in [1, z_x]$. Also note that $g_2 > g_x > g_d(z)$. This implies that the denominator in the left-hand side of equation (18) is positive, and thus $g_d'(z) > 0$. $\square$

The intuition behind Proposition 1 is the following. The possibility of future exports represents an option value for the firm. The value depends on the probability that it will become an exporter (i.e., will not die before reaching z_x). As firms grow they approach z_x and the probability increases. The present value of the firm increases faster, and the growth rate increases (the second derivative $V_d''(z)$ is positive, so through equation (14), $g_d(z)$ is increasing). In turn, the option value is increasing in exporting profits. Higher trade costs reduce those profits, thereby reducing the innovation and growth rates of non-exporters. Similarly, a higher sunk export cost increases the threshold z_x, making exporting more difficult to achieve and reducing the option value as well as innovation itself. Thus, policies that affect the exporting sector have a direct effect, through firm life cycle, on the non-exporting sector.

These are new predictions about the effect of trade barriers on non-exporters that challenge the existing literature. First, they suggest that firms that anticipate exporting may start growing faster before beginning to export. This is consistent with what Bernard and Jensen (1999) find for U.S. firms. Based on their findings, they conclude that firms became better for reasons other than exporting, and that such firms export as a byproduct of their increased productivity. Our model suggests that their productivity grew faster because they knew they would become exporters.

Second, our predictions have implications for the literature that measures the impact of trade costs on firm productivity by using non-exporters as a control group, that is, assuming that trade costs do not affect them. We find that trade barriers also affect non-exporters.

The firm size distribution. The model delivers the distribution of exporters in closed form solution. To characterize the full distribution, we approximate the differential equation determining the growth rate of non exporters using the functional form $g_{dj}(z) = (a_j + b_j z + c_j z^2 + d_j z^3)^{-1}$, where $a, b, c,$ and d are parameters to be determined in equilibrium. We show in Appendix A that the steady-state distribution is:[9]

$$\mu_j(z) = \begin{cases} M_j \exp\left[\delta(b_j(1-z) + c_j/2(1-z^2) + d_j/3(1-z^3))\right] z^{-a_j\delta}, \text{ if } z < z_{xj} \\ M_j A_j z^{-\frac{\delta}{g_{xj}}}, \text{ if } z \geq z_{xj} \end{cases} \tag{19}$$

where $A_j = z_{xj}^{(\delta/g_{xj} - a_j\delta)} \exp(b_j(1-z_{xj}) + c_j/2(1-z_{xj}^2) + d_j/3(1-z_{xj}^3))$.[10]

It is straightforward to see that μ_j satisfies Zipf's law. This law states that the upper tail of the distribution of firms according to employees (or sales) follows a Pareto distribution. The upper tail is completely populated by exporters. The distribution of exporters is Pareto in z. Since employees (and sales) are linearly proportional to z, this satisfies Zipf's law.

Solution to the system. Given this distribution, we solve for the equilibrium in each country by solving a system of three unknowns (π_{dj}, M_j and w_j) and three equations: free entry (11), labor-market clearing (2), and trade balance.

It is convenient to rewrite labor-market clearing and trade balance in terms of the unknowns.

Labor market clearing is

$$\frac{L_j}{M_j} = \int_1^\infty n_j(z)\hat{\mu}_j(dz) + (1+\tau_{xj})\int_{z_{xj}}^\infty n_{j,*}(z)\hat{\mu}_j(dz) + \int_1^{z_{xj}} \frac{z\kappa_{Ij}}{2} g_{dj}^2(z)\hat{\mu}_j dz + \hat{\mu}_j(z_{xj}) + \kappa_e$$

and trade balance is

$$(\pi_{xj} - \pi_{dj})\int_{z_{xj}}^\infty z\mu_j(dz) = (\pi_x^* - \pi_d^*)\int_{z_x^*}^\infty z\mu^*(dz) \tag{20}$$

Given w_j, we pin down prices $p(z)$. With π_{dj}, we determine the labor used in production per firm, their innovation and the distribution of firms up to a scalar M_j.

Aggregate productivity. We derive a measure of productivity as in Atkeson and Burstein (2010). This is output per production worker, where output is defined as the CES aggregate good (Q_j

[9] All Appendices are available online at `https://sites.google.com/a/asu.edu/loris-rubini/Appendices.pdf?attredirects=0`

[10] The non-exporter's growth rate is defined implicitly by $\frac{-g_2 \log\left(\frac{g_d(z)-g_2}{g_x-g_2}\right) + g_1 \log\left(\frac{g_d(z)-g_1}{g_x-g_1}\right)}{(g_2-g_1)} = \frac{1}{2}\log\left(\frac{z}{z_x}\right)$, making it clear that the solution is smooth and can be approximated arbitrarily closely by a polynomial. In fact, the quantitative section shows that the fit of the approximation is very good.

in equation (1)). We show in the online Appendix B that the following holds:

$$Q_j = Z_j N_{pj}$$

where N_{pj} is labor used in production and Z_j is a constant (productivity), with

$$Z_j^{\sigma-1} = \int_1^{\infty} z\mu_j(dz) + (1+\tau_x^*)^{1-\sigma} \left(\frac{w^*}{w_j}\right)^{1-\sigma} \int_{z_x^*}^{\infty} z\mu^*(dz) \tag{21}$$

$\int_1^{\infty} z\mu_j(dz)$ is a measure of the average productivity of the domestic firms, and $\int_{z_x^*}^{\infty} z\mu^*(dz)$ is a measure of the average productivity of imports.

2.3 The Closed Economy

In the closed economy, there is only one type of firm, and their maximization problem is similar to the problem of exporters. Notice that we need to normalize one price for each economy, so that $w_j = 1$ for all j.

Static profits are given by $\pi_j(z) = \pi_j z$, and the value function is $V_j(z) = \kappa_{Ij} g_j z$, where $g_j = (\rho+\delta)\left(1-\sqrt{1-h_j}\right)$ where $h_j = 2\pi_j/((\rho+\delta)^2\kappa_{Ij})$. The free-entry condition pins down the rate of growth of firms in the economy by setting $\kappa_e = \kappa_{Ij} g_j = V_j(1)$. The distribution of firms is given by $\mu_j(z) = M_j z^{-\delta/g_j}$.

3 Open vs. Closed Economies

Next, we compare two types of results based on the open and closed economy assumptions. First, we show that the closed economy underestimates innovation costs, because it does not capture the innovation incentives associated with exporting. Our findings indicate that exporting not only increases the innovation of exporters, but also of non-exporters who anticipate becoming exporters in the future.

Second, we compare the effect of increasing innovation costs on welfare, and find that the closed economy always exaggerates the welfare loss. In our analysis, exporters shift sales towards the export market when faced with larger domestic innovation costs. The reason is that higher innovation costs reduce profits, which reduces domestic income, lowering domestic demand relative to foreign demand. Thus, the reduction in demand faced by firms in the closed economy is larger than that faced by firms in the open economy, amplifying the response of aggregate welfare.

3.1 Estimates of Innovation Costs

The key calibration target to estimate these costs in the closed economy is the slope of the upper tail of the distribution of firms. In the open economy, we draw additional information from export data: the share of firms that export and the ratio of exports to total sales in an economy. When data on export behavior is not considered, something is lost. This section derives analytical results to understand what exactly is lost and how it affects estimates and counterfactuals. Section 5 shows the magnitude of these differences when the model is calibrated to key moments in the data.

We set the innovation costs in the closed and open economies so that the distribution of large firms is the same in both economies. Large firms are the exporters in the open economy, as are all firms in the closed economy.

Proposition 2 shows that the estimated innovation costs under the closed economy assumption are always smaller than under the open economy assumption. Further, in a corollary we show that openness affects countries differently, and as a result country efficiency rankings may change.

Proposition 2 *Assume that the slope of the upper tail of distribution in the closed and open economy models in country j is the same. Let κ_j^c be the estimated innovation cost under the closed economy assumption. Then, $\kappa_j^c < \kappa_{Ij}$ for all j.*

Proof: See Appendix C. The proof arrives, via algebra calculations, to the following expression:

$$2\kappa_e(\rho+\delta)\left[\frac{1}{\kappa_j^c}-\frac{1}{\kappa_{Ij}}\right]=g_{xj}^2-g_{dj}(1)^2+\frac{2\pi_d^*}{w_j\kappa_{Ij}}\left(D_j\frac{w_j}{w^*}\right)^{1-\sigma} \tag{22}$$

Since profits are always positive and by Proposition 1, $g_{xj} > g_{dj}(1)$, the right hand side of the above equation is positive. Thus, it must be the case that $\frac{1}{\kappa_j^c} > \frac{1}{\kappa_{Ij}}$, or $\kappa_j^c < \kappa_{Ij}$. □

The closed economy, therefore, underestimates innovation costs. Intuitively, the reason is that trade adds incentives for innovation. If the incentives are greater, the estimation delivers higher costs to generate the same slope of the distribution of firms. In the quantitative section, we show that the downward bias of domestic innovation costs in the closed economy assumption effect is actually sizeable.

Notice that we can use equation (22) to identify the effects of the additional incentives that exporting provides on the bias in innovation costs. Let $\tilde{g}$ be the rate of growth chosen by a firm that would never expect to export (for example, if $\kappa_x = \infty$ for that firm). This rate of growth is

$$\tilde{g}_i = (\rho + \delta)(1 - \sqrt{1 - \tilde{h}_i}), \text{ where } \tilde{h}_i = \frac{\pi_{di}}{(\rho + \delta)^2 \kappa_{Ii}}$$

Inserting this into equation (22),

$$\left[\frac{1}{\kappa_j^c} - \frac{1}{\kappa_{Ij}}\right] = \frac{\left(g_{xj}^2 - \tilde{g}_j^2\right) - \left(g_{dj}(1)^2 - \tilde{g}_j^2\right) + \frac{2}{w_j \kappa_{Ij}}\left(\pi_{xj} - \pi_{jj}\right)}{2\kappa_e(\rho + \delta)} \tag{23}$$

Notice the intuition behind equation (23). The bias depends on static and dynamic components. The last term on the right hand side measures the static component: it is a function of the additional profits an exporter receives.

The first two terms on the right hand side of equation (23) are the dynamic components in the bias. $g_{xj}^2 - \tilde{g}_j^2$ is a measure of the additional incentives of exporters. However, not all firms export so not all firms face these additional incentives. Equation (23) adjusts this difference by subtracting the term $g_j(1)^2 - \tilde{g}_j$. This difference is the additional incentives non-exporters have because of the possibility of exporting in the future.

The fact that $g_j(1)^2 > \tilde{g}_j$ follows from 1. This suggests that non exporters invest to export, that is, they increase their growth rate anticipating higher returns in the future, when they become exporters. By increasing their growth rates, these firms start exporting sooner, increasing the present value of the firm.

What about the differences between two countries? Suppose $\kappa_{I2} < \kappa_{I1}$. What is $\kappa_2^c - \kappa_1^c$?

Corollary 1 *The difference in innovation cost estimates between countries in the closed economy model* *is given by*

$$\kappa_j^c - \kappa_i^c = K_1(\kappa_{Ij} - \kappa_{Ii}) + K_2[(g_{xi} - \tilde{g}_i) - (g_{xj} - \tilde{g}_j)] + \frac{K_2}{2(\rho+\delta)}[(g_{dj}(1)^2 - \tilde{g}_j^2) - (g_{di}(1)^2 - \tilde{g}_i^2)]$$

where $0 < K_1 = \frac{\kappa_i^c \kappa_j^c}{\kappa_{Ii}\kappa_{Ij}} < 1$*,* $K_2 = \frac{\kappa_i^c \kappa_i^c}{\kappa_e} > 0$ *and* $\tilde{g}_i = (\rho+\delta)(1 - \sqrt{1-h_i}), h_i = \frac{\pi_{di}}{(\rho+\delta)^2 \kappa_{Ii}}$ *is the rate at which a firm would grow if it never expects to export.*

Proof: See online Appendix D.

Corollary 1 splits the estimated difference in innovation costs into three components. The first component is the difference in innovation costs under the open economy assumption. The larger this difference, the larger the difference in the estimates under the closed economy, since $\alpha > 0$. The second component depends on the innovation incentives for exporters, relative to a hypothetical firm that never expects to export[11] $(g_{xi} - \tilde{g}_i)$. The third component relates to the incentives for non-exporters. The difference $g_i(1) - \tilde{g}_i$ denotes the additional incentives of an entrant that expects to export in the future relative to a firm that would never do so. The implication of $g_{di}(1) > \tilde{g}_i$ is that firms invest to export.[12]

A result that follows from this corollary is that rankings of countries according to their innovation cost may change depending on whether we model an open or closed economy. In other words, for a country pair i, j, we could have $\kappa_j^c - \kappa_i^c > 0$ and $\kappa_{Ij} - \kappa_{Ii} < 0$. We show in the quantitative section that this is not only a theoretical curiosity but that it actually happens for some countries.

3.2 Counterfactuals

We show that, for a special case, the closed economy overpredicts the effects of counterfactuals on productivity and welfare whenever domestic firms shift output toward exports when innovation costs increase. This special case assumes that $\kappa_x = 0$, so all firms export. Moreover, if $\sigma \leq 3/2$, we show that an increase in innovation costs drives firms to increase the share of output exported. These are sufficient conditions that simplify the algebra considerably, allowing us to make compelling theoretical statements about the effects of changing innovation costs.

[11] While in the model every firm will export at some point, $\tilde{g}_i$ is the growth rate of a hypothetical firm whose trade costs are infinite, and therefore never exports.

[12] Notice that we require that in equilibrium $g(1) > \tilde{g}_i$. This holds in the quantitative section.

The intuition underlying this result is the following. Consider an increase in the domestic κ_I. On the one hand, this drives firms to reduce innovation, decreasing aggregate productivity and welfare. On the other hand, associated with the increase in κ_I is an aggregate negative income effect, which reduces profits, and thus innovation, productivity and welfare fall even more. In the open economy, faced with the reduction in domestic demand, firms increase the proportion of exports in total sales, thereby reducing their losses. Thus, welfare falls less than in the closed economy model.

We start by showing some closed-form solutions for key variables in equilibrium, and then use these forms to prove the main proposition of this section: that in the closed economy, counterfactuals are overpredicted in the closed economy. An argument similar to that set forth in section 2.2 shows that $g_x(z) = g_x$ for all z. That is, as before, all exporters grow at the same, constant rate, independently of size. Also, it is easy to show that the value function in equilibrium is $V_x(z) = \kappa_I g_x z$. Evaluating at $z = 1$ and adding the free-entry condition shows that in equilibrium, the growth rate of exporters is $g_x = \frac{\kappa_e}{\kappa_I}$. This demonstrates clearly the effect of a change in innovation costs on firm growth rates, that is, $\frac{\partial g_x}{\partial \kappa_I} = -\frac{\kappa_e}{\kappa_I^2}$. From this, we derive closed-form solutions for the distribution of firms. Recall that the distribution of firms is $\mu(z) = M z^{\frac{-\delta}{g_x}}$, so we need a closed-form solution for M. Market clearing determines M:

$$\frac{L}{M} = \left[\frac{\pi_x}{w} + \frac{\kappa_I g_x^2}{2}\right] \int_1^\infty z^{1-\frac{\delta}{g_x}} + \kappa_e$$

Next, by normalizing $L = 1$ we can rewrite the value function for an entrant as $V_x(1) = \frac{\pi_x}{w} + \frac{\kappa_I g_x^2}{2} = \kappa_e$. Thus, $\frac{1}{M} = \kappa_e \left(\frac{1}{\frac{\delta}{g_x} - 2} + 1\right)$. Rearranging terms and replacing g_x with its value in equilibrium gives

$$M = \frac{\delta\kappa_I - 2\kappa_e}{\delta\kappa_I\kappa_e - \kappa_e^2} \qquad \text{and} \qquad \mu(z) = \frac{\delta\kappa_I - 2\kappa_e}{\delta\kappa_I\kappa_e - \kappa_e^2} z^{-\frac{\delta\kappa_I}{\kappa_e}}$$

We then define Z_x as the productivity in the open economy and Z_c as the analogue under the closed economy assumption. The following proposition states the relationship between these two.

Proposition 3 *Aggregate productivity in the open economy exceeds aggregate productivity in the closed economy by a factor proportional to the fraction of output exported. In equations,* $Z_x = Z_c \frac{\pi_x}{\pi_d}$ *where*

$Z_x = Z^{\frac{1}{\sigma-1}}$ as defined in equation (21) and $Z_c = \int_1^\infty z\mu(z)dz$ (the analogue to Z_x in the closed economy).

Proof: Start with the definition of Z_x and Z_c.

$$Z_x = \int_1^\infty z\mu_x(dz) + w^{\sigma-1}X^*, \qquad Z_c = \int_1^\infty z\mu_c(dz)$$

where $X^* = (1+\tau_x^*)^{1-\sigma}w^{*1-\sigma}\int_1^\infty z\mu^*(z)dz$.

From trade balance,

$$w^{\sigma-1}X^* = \frac{\pi_x - \pi_d}{\pi_d}\int_1^\infty z\mu(z)dz$$

Thus

$$Z_x = \left(1 + \frac{\pi_x - \pi_d}{\pi_d}\right)\int_1^\infty z\mu(z)dz = \frac{\pi_x}{\pi_d}\int_1^\infty z\mu(z)dz$$

Next let $\mu_c(z)$ be the distribution in the closed economy. Since the growth rate of firms must be the same in the open and closed economies to match the same distribution of firms in equilibrium, it follows that $\mu_c(z) = \mu(z)$ for all z, and $\int_1^\infty z\mu(z)dz = \int_1^\infty z\mu_c(z)dz = Z_c$. $\square$

Note the intuition underlying this proposition. Productivity in the open economy is productivity in the closed economy times the ratio π_x/π_d, which is larger than one. More importantly, a change in innovation costs will affect productivity in the open economy in two ways: the direct effect on the distribution of firms, which operates exactly as in the closed economy, and the effect on firms' exposure to trade. This leads to the following proposition:

Proposition 4 *When changing innovation costs, the change in productivity in the open economy relative to the close economy is equal to the change in π_x relative to π_d. That is,*

$$\frac{\partial(Z_x/Z_c)}{\partial\kappa_I} = \frac{\partial(\pi_x/\pi_d)}{\partial\kappa_I}$$

Proof: The proof is in online Appendix E. Intuitively, we first show $Z_x = Z_c\frac{\pi_x}{\pi_d}$. According to the proposition, when κ_I increases, Z_c falls and Z_x falls, but π_x/π_d increases, so the change in Z_c is larger than the change in Z_x.

Corollary 2 *If $\sigma < 3/2$, a change in κ_I has a larger effect on aggregate productivity in the closed economy than in the open economy.*

Proof: See online Appendix E. Intuitively, $\sigma < 3/2$ guarantees that $\frac{\partial(\pi_x/\pi_d)}{\partial\kappa_I} > 0$.

Corollary 2 is only a sufficient condition. Numerically, we found $\frac{\partial(\pi_x/\pi_d)}{\partial\kappa_I} > 0$ is true for all values of σ. A small σ helps because it increases the returns to scale in the economy, and thereby increases the gains from trade. In the extreme case where $\sigma = \infty$, there are no gains from trade.

4 Data and Calibration

4.1 Data

We use the European Firms In a Global Economy (EFIGE) database, which contains detailed manufacturing-firm-level information for almost 15,000 firms in seven European countries: Austria, France, Germany, Hungary, Italy, Spain, and the U.K. Austria and Hungary are not included in the analysis, as their data samples are too small (less than 500 firms in each country).[13] We exclude firms that do not export but maintain some kind of international activity, such as importing, being part of a multinational, or investing abroad, since we do not model these activities. The remaining sample is of 13,401 firms.[14]

First we document large differences in employee-size distributions across the European countries. France, Germany, and the U.K. have relatively larger firms than Italy and Spain. The latter countries have the lowest productivity in the sample according to several definitions of productivity[15], an observation that is consistent with Tybout (2000), who surveyed the literature on firm size distribution and noted that countries with relatively smaller firms have lower GDP per capita.

Figure 1 shows these distributions. It includes firms with more than 30 employees and drops the 1 percent largest firms. The x-axis plots the log of employees, and the y-axis plots the log of the share of firms with more than x employees. The slope of this figure shows the "speed" at which the mass of

[13] Rubini et al. (2012) performs a similar analysis to this paper that includes all seven countries.

[14] Figures 1 and 2 would hardly change by including these firms. Figure 3 would, if it includes firms that belong to a multinational organization.

[15] For example, figure 4 shows how these countries compare in manufacturing value added per worker.

given sizes decreases: a steeper slope implies a relatively higher number of small firms. The difference is robust to a number of control variables and to a one-digit-level industry (higher digit levels imply very few firms in some industries). Also, the estimation is robust to different minimum employee thresholds.

One determinant that is highly relevant is export status. Figure 2 shows the distribution excluding non-exporters. At first glance, the picture looks the same as Figure 1. In contrast, Figure 3 shows only non-exporters. Here we see important differences. While Italy still has the steepest distribution, Spain is now closer to France and the U.K. Germany has the flattest distribution. Thus, trade costs are important in accounting for differences in distributions.

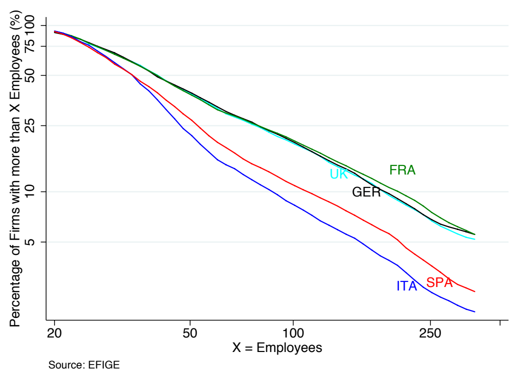


Figure 1: Firm Size Distributions

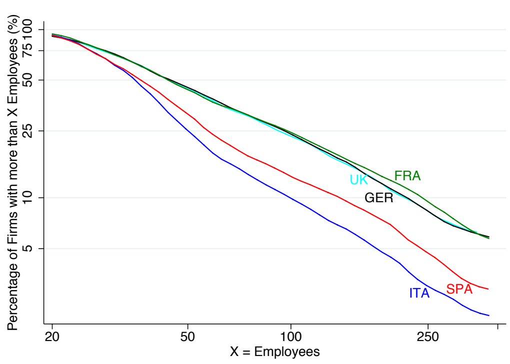


Figure 2: Exporters' Distributions

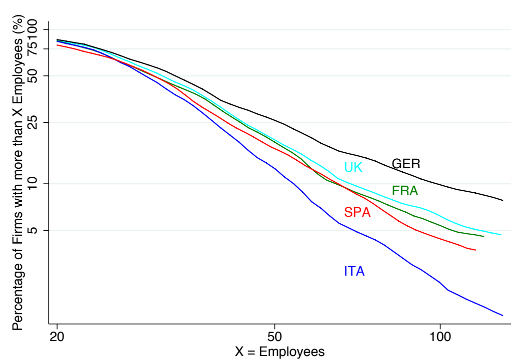


Figure 3: Non-exporters' Distributions

4.2 Calibration

We add labor and corporate taxes. Labor tax data, which are from McDaniel (2007) using the 2007-2009 average, drive a wedge between the labor cost faced by firms and that received by a worker, so that if a worker receives a wage w, the cost per employee for a firm is $(1+\tau_l)w$, where τ_l is the labor tax rate. Profit tax data are from the *Doing Business* report for 2012 (the only year with data). Firms maximize after-tax profits $(1-\tau_c)\pi$, where τ_c is the corporate tax rate. Innovation is not deducted from taxes.

To calibrate the rest of the world, we normalize the iceberg trade cost for one country (we set $\tau_{x,GER}=0$). This does not affect the ratio $\frac{1+\tau_{xj}}{1+\tau_{x,GER}}$, and it implies that we do not need to calibrate the rest of the world. Thus, our trade costs are relative to Germany's.

4.3 Calibration Strategy

The following parameters are calibrated independently: tax rate, size of the economy, and death rate. We calibrate the parameters κ_I, τ_x and κ_x jointly to match the slope of the distribution of large firms, the share of firms that export, and the aggregate trade volume, defined as the sum of exports divided by total sales. g_{xj} is determined by the slope of the distribution of firms. z_{xj} is sensitive to the fraction of exporters and τ_{xj} is sensitive to the export volume.

Upper tail of the distribution. First, from the slope of the firm size distribution we determine the exporter growth rate in equilibrium. From equation (19), the distribution of exporters in country j is $\mu_{xj}(z)=A_j z^{-\frac{\delta}{g_{xj}}}$, where A_j is a constant defined in equation (19). To be consistent with figures 1 through 3, we focus on the measure

$$\ln \int_x^\infty \mu_{xj}(z)dz = \tilde{A}_j + \left(1-\frac{\delta}{g_{xj}}\right)\ln x \tag{24}$$

with $\tilde{A}_j = \ln\left(\frac{A_j}{\frac{\delta}{g_{xj}}-1}\right)$. Thus, the slope of the distribution is $\left(1-\frac{\delta}{g_{xj}}\right)$. Given δ, this determines g_{xj}. From equation (6) g_{xj} determines the value of $\frac{\pi_{xj}}{w_j\kappa_{Ij}}$, which allows us to write κ_{Ij} as a function of $\frac{\pi_{xj}}{w_j}$. Simultaneously, since $\pi_{xj}=\pi_{dj}+(1+\tau_{xj})^{1-\sigma}\pi_d^*$, we end up with κ_{Ij} as a function of $\frac{\pi_{dj}}{w_j}$ and τ_{xj} (assuming that π_d^* is known, which we deal with shortly).

Share of exporters. Given g_{xj}, we choose the value of z_{xj} such that we match the share of firms that export in each country. That is,

$$Sh.Exp._j = \frac{\int_{z_{xj}}^{\infty} \mu_j(dz)}{M_j} = \frac{A_j}{\delta/g_{xj} - 1} z_{xj}^{1-\delta/g_{xj}} \tag{25}$$

Trade Volume. The next key target is the ratio of exports to total sales, or trade volume. Trade volume in country j is

$$TV_j = \frac{(1+\tau_{xj})^{1-\sigma} \frac{\pi_d^*}{(1+\tau_l^*)w^* M_j} \int_{z_{xj}}^{\infty} z\mu_j(dz)}{1 + (1+\tau_{xj})^{1-\sigma} \frac{\pi_d^*}{(1+\tau_l^*)w^* M_j} \int_{z_{xj}}^{\infty} z\mu_j(dz)} \tag{26}$$

where $\tau_{lj}(\tau_l^*)$ is the labor tax in country j (rest of the world). The calibration works by finding the values of κ_{Ij}, κ_{xj} and τ_{xj} such that equations (24),(25) and (26) hold in equilibrium.

Rest of the world. So far we have assumed that the demand and supply of the rest of the world is known. Next we explain how we parameterize this. Foreign demand is

$$\pi_{xj} - \pi_{dj} = (w_j(1+\tau_{lj}))^{1-\sigma} \frac{(1+\tau_{xj})^{1-\sigma}\pi_d^*}{(w^*(1+\tau_l^*))^{1-\sigma}}$$

The supply is the right-hand side of the trade balance equation, which is

$$(1+\tau_{xj})^{1-\sigma}\pi_d^* \int_{z_{xj}}^{\infty} z\mu_j(dz) = \frac{\pi_{dj}}{((1+\tau_{lj})w_j)^{1-\sigma}} (1+\tau_x^*)^{1-\sigma}((1+\tau_l^*)w^*)^{1-\sigma} \int_{z_x^*}^{\infty} z\mu^*(dz)$$

The parameters to be calibrated are therefore $\pi_d^*/(w^*(1+\tau_l^*))$ and $X^* = (1+\tau_x^*)^{1-\sigma}((1+\tau_l^*)w^*)^{1-\sigma} \int_{z_x^*}^{\infty} z\mu^*(dz)$. First, note that we cannot identify $\pi_d^*/(w^*(1+\tau_l^*))$ from the τ_{xj}'s, since the terms are always together. We normalize $\tau_{x,GER} = 0$, and therefore express each countrys trade costs relative to Germany's. Thus, we calibrate $\frac{\pi_d^*}{(1+\tau_l^*)w^*}$ so that equation (26) holds for Germany with $\tau_{x,GER} = 0$. We then set $\tau_{xj}, j \neq GER$ so that equation (26) holds for all other countries given the value of $\frac{\pi_d^*}{(1+\tau_l^*)w^*}$. This identifies the iceberg cost in country j relative to Germany's iceberg cost.

Similarly, we proceed to calibrate the supply from the rest of the world, which is used to find relative wages across countries. The trade balance equation can be written as

$$(\pi_{xj} - \pi_{dj}) \int_{z_{xj}}^{\infty} z\mu_j(dz) = \frac{\pi_{dj}}{((1+\tau_{lj})w_j)^{1-\sigma}} (1+\tau_x^*)^{1-\sigma}((1+\tau_l^*)w^*)^{1-\sigma} \int_{z_x^*}^{\infty} z\mu^*(dz)$$

Let $X^* = (1+\tau_x^*)^{1-\sigma}((1+\tau_l^*)w^*)^{1-\sigma} \int_{z_x^*}^{\infty} z\mu^*(dz)$. As it turns out, the value of this expression is not important, as long as it is the same for every country. The trade balance equation determines relative wages. Divide the value of exports in country j by the analogue for Germany, using $w_{GER} = 1$ as the numeraire:

$$\frac{(\pi_{xj} - \pi_{dj}) \int_{z_{xj}}^{\infty} z\mu_j(dz)}{(\pi_{x,GER} - \pi_{d,GER}) \int_{z_{x,GER}}^{\infty} z\mu_{GER}(dz)} = \frac{\frac{\pi_{dj}}{((1+\tau_{lj})w_j)^{1-\sigma}}}{\frac{\pi_{d,GER}}{((1+\tau_{l,GER}))^{1-\sigma}}} \tag{27}$$

Given π_{dj} we can determine $z_{xj}, z_{x,GER}$ and $\mu_j(z), \mu_{GER}(z)$, pinning down the left-hand side. On the right-hand side the only unknown in this equation is w_j.

4.4 Calibration Targets

The numeraire is the wage rate in Germany, which we set to 1. We set $\rho = 0.04, \delta = 0.06$ and $\sigma = 5$, following Atkeson and Burstein (2010). We use the EFIGE database to calibrate the size of each economy L_i, the innovation cost κ_{Ii}, the fixed export cost κ_{xi} and the variable export cost τ_{xi} (four parameters per country). We use four targets from the EFIGE database and clean the database by eliminating firms that do not export but have some foreign operations, such as importing and investing abroad. The targets are:

- The number of workers in each country;
- The slope of the distribution of exporters. We calculate the slope by focusing on firms with more than 29 employees since we are mostly interested in the upper tail[16];
- The share of firms that export;

[16] We have also experimented with other cutoffs and the results are similar. Problems appear when the cutoff becomes too small in the sense that the slope for the U.K. becomes less than 1. We should mention that when the cutoff becomes too large, the slopes tend to become more similar. A problem with cutoffs that are too large is that very few firms remain in the sample.

- The value of exports relative to the value of production (trade volume). This is problematic since firms do not report their sales. However, they do report the number of employees and the share of output exported. Thus, our measure of trade volume in country i is the sum of employees in country i times the export ratio divided by the sum of employees in country i.

Table 1: Calibration Targets and Relevant Parameter

Country	Employment	Exp Vol	Exp Firms	Slope	Profit Tax	Labor Tax
France	2,903,820	27%	71%	1.11	8%	10%
Germany	5,739,365	20%	65%	1.16	19%	10%
Italy	3,555,052	33%	77%	1.42	23%	14%
Spain	2,010,424	21%	68%	1.27	1%	9%
U.K.	3,768,663	26%	73%	1.06	23%	15%
Parameter	L	τ_x	κ_x	κ_I	τ_π	τ_l

Table 1 shows the calibration targets. A key step in this calibration is the approximation of non-exporter growth rates. In online Appendix F we show the values for the fitted parameters and compare the numerical solution to the approximation for the growth rates and value functions. Figures F.1 through F.5 in online Appendix F show that, in most cases, the approximation is indistinguishable from the numerical solution.

5 Quantitative Results

Table 2 contains the values for calibration of the key parameters and the implied exporter growth rates. Costs are normalized so that they equal 1 in Germany.

Table 2: Growth Rates and Parameter Values

Country	g_x	κ_I	κ_x	$1+\tau_x$
France	2.84%	1.08	1.48	1.00
Germany	2.78%	1.00	1.00	1.00
Italy	2.48%	1.33	1.67	0.92
Spain	2.64%	1.07	1.02	1.43
U.K.	2.91%	1.02	1.24	0.92

Consider Italy and Spain, the countries with the flattest distributions. This flatness is consistent with the low rates of growth we have identified. Italy has low growth rates mainly because innovation costs are 33% higher than in Germany. Spain, on the other hand, has a hard time exporting, which costs 43% more for Spain than Germany.

We can also learn from the behavior of the remaining countries. France has higher costs than Germany, particularly higher sunk export costs, and still its exporters grow faster. The larger sunk export costs act as a barrier to entry into the export market, which reduces competition; and as a result insiders enjoy larger profits and innovate more, growing faster.[17] U.K. exporters grow fast because sunk export costs are higher and the variable trade costs are lower than in Germany. This more than compensates for a slightly higher cost of innovation, resulting in a higher growth rate.

Before moving any further, we try to understand the magnitude of these estimates, by focusing on innovation costs and iceberg costs. Innovation costs are related to the ease with which firms grow. For example, our estimates suggest that it is much costlier to grow in Italy than in any other country in the sample. This result is supported by World Bank estimates of the ease of doing business in each country based on a number of costs, such as those related to construction permits, registering property, obtaining credit, and enforcing contracts. Based on these (and additional) categories, the World Bank ranks each country; these rankings are shown in Table 3 alongside our estimates of innovation costs.

Table 3: Doing Business Report Ranking (2011)

Country	Ease of Doing Business Rank	κ_I
France	26	1.08
Germany	19	1.00
Italy	83	1.33
Spain	45	1.07
U. K.	6	1.02

Source: http://www.doingbusiness.org

The order of the World Bank ranking agrees with our estimates. The only exception is the U.K., where it is easier to do business than in Germany according to the report, but not according to our

[17]Note that this is a general equilibrium effect. As pointed out in Proposition 1, the partial equilibrium effect is that a larger trade cost (fixed or variable) reduces the growth rate.

estimates of innovation costs.

Next we turn to iceberg costs. Waugh (2010) estimates trade costs for many countries, including all the countries we consider except Germany. Table 4 shows his estimates of trade costs relative to France for the four countries we have in common as well as our estimates. Both show that Spanish trade costs are the highest, although our differences are larger than his.

Table 4: Waugh's Trade Cost Estimates

Country	Waugh	$1 + \tau_x$
U.K.	0.85	0.92
Italy	1.04	0.92
France	1.00	1.00
Spain	1.18	1.43

Source: Waugh (2010)

Another characteristic that may contribute to Spain's high export costs is its distance from customers relative to the other countries, which naturally increases transport costs. Table 5 reports the share of exports within Europe, to North America, and to South and Central America (based on EFIGE data on where products are shipped). The farthest destination is South and Central America, and the country exporting the most to South and Central America is Spain.

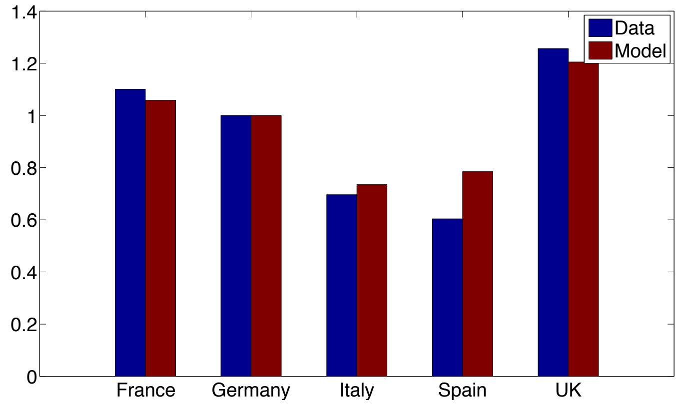
Table 5: Export Destination

Country	Europe	North America	South and Central America
France	76%	6%	2%
Germany	81%	6%	2%
Italy	79%	6%	3%
Spain	73%	4%	8%
U.K.	67%	12%	1%

Source: EFIGE

There is additional data that supports our findings regarding high exports costs in Spain. The World Bank reports measures of export costs. These measures are used as reference when comparing countries that choose similar export methods. This is the case of Italy and Spain, two peninsulas, with a natural advantage in maritime exporting. The World Bank reports two significant differences that increase export costs in Spain relative to Italy: (i) Spanish exports require 50% more paperwork than Italian

Figure 4: Manufacturing Value Added per Worker (Germany = 1)



exports (an average of 4 documents in Italy vs. 6 in Spain); and (ii) the time required for Spanish goods to reach the port of departure after leaving the factory is 50% longer (2.6 days in Italy vs. 4 days in Spain). This last point may well be due to geography. While both countries are peninsulas, Italy has a relatively narrower land area surrounded by water. Thus, there are many more ports in Italy than Spain: 212 vs. 105. These are the total number of ports, but only the largest are used to export goods. In Spain, Barcelona is the only large port, while Italy has five major ports: Genoa, La Spezia, Livorno, Venice, and Naples.[18]

6 The Model Along Non-targeted Dimensions

6.1 Value Added Per Worker: Model vs. Data

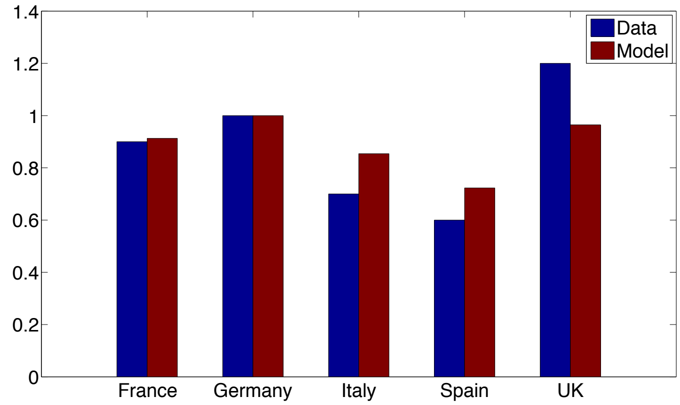
Value added per worker data is from Eurostat, specifically the average from 2004 through 2010. As shown in Figure 4, the model performs exceptionally well, accounting for a large fraction of the differences in value added per worker in the manufacturing sector in these economies. Table 6 provides the value added per worker in the data with the model, showing that the model accounts for 54 to 87 percent of the differences. It is worth mentioning that the accounting of the closed economy model would be very similar, except that the closed economy would attribute this entirely to differences in innovation costs, ignoring the effect of trade barriers.

[18] http://www.worldportsource.com.

Table 6: Manufacturing Value Added per Worker Relative to Germany

Country	Data	Model	Model accounting
France	1.10	1.06	58%
Italy	0.70	0.74	87%
Spain	0.60	0.78	54%
U.K.	1.26	1.21	80%

Figure 5: Mean Hourly Wages (Germany = 1)



6.2 Wages: Model vs. Data

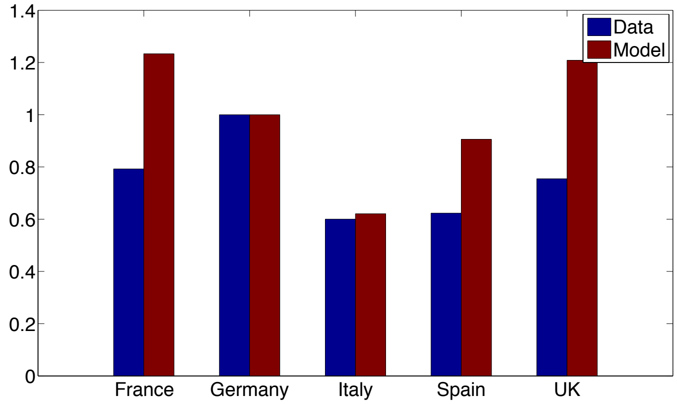
Next we compare wages in the model and the data. Eurostat data for 2006 is used, since the 2008 survey did not include data for the U.K. The wages in the model are compared with the mean hourly wage relative to Germany in the data. As shown in Figure 5, the model does a good job of generating the wage differences we observe in the data.

6.3 Innovation: Model vs. Data

We compare innovation in the model with R&D in the data. The EFIGE database has information on the fraction of employees devoted to R&D in each firm. However, since R&D is only part of innovation, we cannot compare the two numbers directly. Instead, we assume that the share of R&D to total innovation is constant in all firms, normalize everything so that the data and model are the same in Germany, and compare it to the levels of the other countries. We ignore missing information observations for our comparison.

The model performs particularly well for Italy. In Spain, France and the U.K. it predicts too many

Figure 6: Share of Employees in R&D (Germany = 1)



employees will go into R&D. The U.K. has a relatively low level of R&D when compared to the rest of the countries. A reason why the model might fail for the U.K. is that many of these firms perform their R&D expenditures abroad, particularly in the United States, as documented by Griffith et al. (2006).

7 Results: Open vs. Closed Economies

We next compare our results with a closed economy model. Because the closed model is what most of the literature focuses on, our results can provide guidance as to how the predictions of such models would be affected by adding international trade. Examples of such models are Luttmer (2007), Luttmer (2010) and Acemoglu and Cao (2010), who develop closed economy models in which firms decide how much to grow by making investments in innovation.

7.1 Estimates of Innovation Costs

Proposition 2 states that the closed economy underestimates innovation costs. Table 7 shows quantitatively the bias introduced by assuming the economy is closed. In the first column, we normalize the innovation cost in the open economy in Germany to one, and express every other cost in terms of it. The second column shows, in absolute terms, the bias implied by assuming the economy is closed. In the third column, we express the innovation costs in the closed economy relative to Germany to create a ranking of the countries costs and compare those costs with the open economy.

Table 7: Innovation Costs: Closed vs. Open Economies

	Open (GER = 1)	Closed / Open	Closed (Closed GER =1)
France	1.07	0.71	0.98
Germany	1.00	0.78	1.00
Italy	1.33	0.65	1.12
Spain	1.07	0.76	1.05
U.K.	1.02	0.73	0.95

The bias introduced by the closed economy assumption is between 22 percent and 35 percent. The country with the largest distortion, both in terms of the actual cost and relative to the other countries, is Italy. Interestingly, the order of the innovation costs ranking changes when we assume the economies are closed. In particular, both France and the U.K. have innovation costs that are larger than Germany's when modelling the open economy, but they appear to be smaller than Germanys under the closed economy assumption.

Corollary 1 provides some intuition as to why the bias is different across countries. The bias will be larger when (i) the difference in actual costs is large; (ii) the difference in exporter growth rates is large; and (iii) the difference in the growth rates of entrants is large. Comparing Italy with Germany, we have already concluded that (i) and (ii) are true, thus accounting for the large bias.

Table 8 shows how the terms in equation (23) account for the bias in the difference $\frac{1}{\kappa_i^c} - \frac{1}{\kappa_i}$. The difference between the first two columns represent the dynamic components of the bias[19] (related to future gains), and the third column represents the static component, as explained in Proposition 2. The fact that stands out the most is how the dynamic component is smaller for Italy and Spain, especially related to the gains once firms become exporters.

Table 8: Decomposing the Innovation Cost Bias into Dynamic and Static Components

Difference accounted for by	$g_x^2 - \tilde{g}^2$	$g_d(1)^2 - \tilde{g}^2$	$\pi_x - \pi_d$
France	0.27	0.07	0.80
Germany	0.29	0.11	0.82
Italy	0.22	0.10	0.88
Spain	0.22	0.08	0.86
U.K.	0.29	0.11	0.82

[19]Recall that $\tilde{g}$ is a hypothetical rate at which a firm would grow if it would expect never to export.

At the other extreme, in Spain the bias in innovation costs is similar to Germany's. As it turns out, the closed economy assumption is not so inaccurate for either country. In Germany, this is because the domestic economy is large and therefore more significant in relation to the rest of the world, while in Spain, this is due to high export costs.

In terms of Corollary 3, while the exporter growth rates are different in these two countries, the entrant growth rate is actually greater in Spain. This compensates for the difference in the exporter growth rate and results in the bias being similar in both countries. Intuitively, the reason why entrant growth rates are so high in Spain is that innovation costs are relatively low and there is not much competition due to high export costs.[20] However, these high trade costs reduce the incentives to innovate, and therefore firm innovation growth is limited.

It is also interesting to compare Spain with France. Under the open economy model, they both have similar innovation costs, but France's costs drop by almost 10 percentage points under the closed economy model, while Spain's remain constant. France's export costs are much lower than Spain's, so the closed economy model introduces a larger bias in France.

7.2 Counterfactuals: Innovation Costs

Proposition 4 showed that counterfactuals react more in the closed economy than in the open economy. Some assumptions are necessary to prove the theoretical results; these assumptions are not met in the quantitative section (for example, no fixed export costs). In this section, we show that in the calibrated model, the closed economy also amplifies the response to counterfactuals. Table 9 shows the elasticity of productivity given a 0.5

Table 9: Elasticity of Productivity to Innovation Costs

Country	Open Economy	Closed Economy	Ratio Closed to Open
France	-0.62	-1.07	1.73
Germany	-0.62	-0.91	1.47
Italy	-0.48	-0.69	1.44
Spain	-0.63	-0.90	1.43
U.K.	-0.64	-1.01	1.58

Table 10: Elasticity of Welfare to Innovation Costs

Country	Open Economy	Closed Economy	Ratio Closed to Open
France	-3.12	-5.13	1.64
Germany	-3.09	-4.37	1.42
Italy	-2.52	-3.29	1.31
Spain	-3.13	-4.31	1.38
U.K.	-3.25	-4.83	1.49

Welfare is the aggregate consumption good C as a measure of welfare. For country j,

$$C_j = \left[\sum_{i=1}^{5} \int_{z_{xi}}^{\infty} q_{ij}(z)^{\frac{\sigma-1}{\sigma}} \mu_i(z) dz + \int_{1}^{z_{xj}} q_{jj}(z)^{\frac{\sigma-1}{\sigma}} \mu_j(z) dz \right]^{\frac{\sigma}{\sigma-1}}$$

From the derivation of productivity, $C_j = Z_j L_{pj}$, where L_{pj} is labor used in production.

As Proposition 4 suggests, productivity reacts more in the closed economy model than in the open economy because increases in innovation costs bring about losses, and exporters can hedge against these losses by focusing more intensively on the foreign market. Table 11 shows the share of exports to total sales per exporter in each country with the calibrated innovation costs, and when these costs increase by 5 percent. Exporters shift their sales toward the export market.

Table 11: Share of Exports to Total Sales by Exporters

	Calibrated κ_I	5% increase in κ_I
France	27.85%	29.59%
Germany	20.97%	22.33%
Italy	34.73%	36.19%
Spain	22.39%	23.75%
U.K.	26.34%	28.09%

7.3 Counterfactuals: Iceberg Trade Costs

The tractability of our model allows us to characterize very precisely the reaction of firms (both exporters and non-exporters) to a change in trade costs. Proposition 1 states that a reduction in trade costs would trigger an increase in the growth rate of non-exporters, in addition to the increase in the growth rate of

[20] Through trade balance, if a countrys exports are low, its imports must also be low.

exporters. While the proposition is based on partial equilibrium, we show in this section that it extends to general equilibrium. Figures 7 through 11 show the behavior of non-exporter growth rates, before and after a 10 percent reduction in iceberg trade costs. The x-axis shows the productivity of the firm, while the y-axis shows the growth rate. The numbers on the x-axis represent export thresholds and the numbers on the y-axis represent exporter growth rates.

As Proposition 1 suggests, the rate of growth is increasing in z and equals the growth rate of exporters at the switching threshold z_x. A reduction in trade costs increases the growth rate for everyone, exporters and non-exporters. It also increases the ratio of exporting firms by lowering the threshold z_x.

Figure 7: French Growth Rates

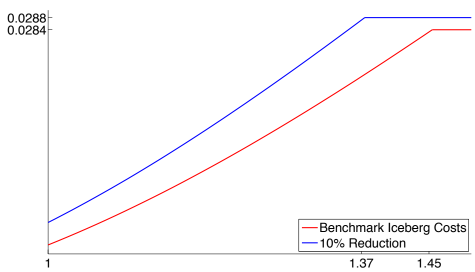


Figure 8: German Growth Rates

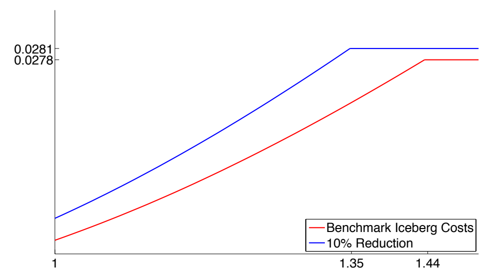


Figure 9: Italian Growth Rates

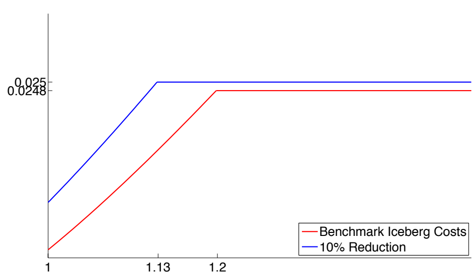
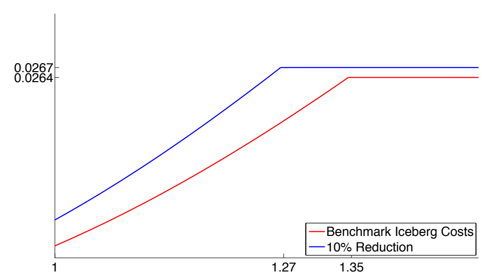


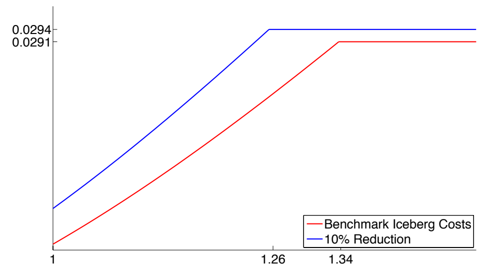
Figure 10: Spanish Growth Rates



The fact that non-exporter behavior changes in response to a change in trade costs has, to the best of our knowledge, not been highlighted so far from a theoretical point of view. This is consistent with Yan-Aw et al. (2011), who by structurally estimating a model of trade with R&D, find that a reduction in trade costs increases the R&D of non-exporters.

Moreover, this contributes to the discussion of whether firms learn by exporting or export because they learn how to be more productive. If firms learn by exporting, then we should observe accelerating

Figure 11: U.K. Growth Rates



growth rates after firms enter the export market. Bernard and Jensen (1999) find that U.S. exporters increase their growth rates before exporting, concluding that there is no evidence of learning by exporting, and therefore trade barriers have little or no effect on firm growth rates. Our model suggests that this observation is consistent with trade barriers being the source of the faster growth: when a firm anticipates becoming an exporter, it is optimal for it to grow faster before exporting.

The positive effect of trade barriers on non-exporters, therefore, suggests the need to be careful when selecting a control group to study those effects. This should be taken into account in papers, such as Van Biesebroeck (2005) and De Loecker (2007), that establish non-exporter firms as a control group.

Next, we consider the aggregate effects of changing trade costs. Atkeson and Burstein (2010) show that adding innovation into a model of trade does not substantially change the gains from reducing iceberg trade costs. Following Atkeson and Burstein (2010), our findings confirm their results. We simulate a reduction in trade costs to determine the elasticity of productivity, then compare these numbers with those of a model with no innovation or fixed export costs, from which we have obtained the elasticity in closed-form solution. We recalibrate this economy so that the trade volumes are the same as in the benchmark model. These numbers are reported in Table 12.

Table 12: Percentage Change in Productivity per Percentage Change in Iceberg Costs

Country	Benchmark Model	No Innovation, All Firms Export
France	-0.30	-0.27
Germany	-0.22	-0.20
Italy	-0.24	-0.33
Spain	-0.22	-0.27
U.K.	-0.25	-0.21

The gains in the model with no innovation are only the direct gains, that is, less is lost in transit.

This implies that any gain in innovation by exporters will be offset by a corresponding reduction in innovation by non-exporters and the measure of entrants in the economy.

8 Conclusion

This paper addresses the question of whether including trade matters when studying barriers to firm growth. While the underlying idea is that it does, as shown by Melitz (2003) and Eaton and Kortum (2002), papers measuring barriers to firm growth abstract from trade barriers to gain tractability.

Using a tractable, dynamic model of trade with endogenous firm growth, we show the consequences of abstracting from trade from a qualitative and quantitative perspective. Qualitatively, the closed economy produces artificially low innovation costs and artificially high counterfactuals. Quantitatively, these effects are large: the closed economy alters the ranking of countries by innovation costs and amplifies the elasticity of welfare to innovation costs by between 31 and 64 percent.

In particular, a closed economy model would conclude that innovation costs in Italy are less problematic than what the open economy model suggests. Moreover, the closed economy model fails to identify the area where Italians excel: exporting. Also, the closed economy model would predict that changes that affect domestic innovation costs have effects that are too large on domestic macro aggregates, such as welfare and productivity. If such a model is used for policy when the economy is indeed open, the analysis will be biased and misleading by a quantitatively large amount.

Finally, we deliver a key message for the empirical estimates of gains from trade. Many trade econometricians estimate the effects of a change in trade policy by comparing the performance of exporters versus non-exporters, under the assumption that non-exporters are not affected by the change in policy. We find that their behavior is not exogenous: both exporters and non-exporters react to a change in trade costs. One prediction present in the literature is that firms that are about to become exporters speed up their growth, consistent with the findings in Bernard and Jensen (1999). While they interpreted this as evidence that trade does not matter for firm growth, our results suggest that trade is key in driving this behavior.

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