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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 this information is key to interpret data and improve 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 under-estimates barriers and amplifies counterfactuals. By calibrating the model to a set of European countries, we find that quantitatively this matters: for example, the closed economy fails to see that Italian firms are very efficient exporters but lousy innovators, and instead conclude 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.

JEL classification: F1; L11; O3

Keywords: Innovation and Trade. Firm Dynamics. Pareto size distribution of firms.

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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: models with endogenous firm sizes allow to back out the relevant barriers by matching the model distribution with its empirical counterpart.[1] Typically, however, these studies assume the economy is closed. We claim that information on exports adds an important dimension beyond the one contained in the size of the firm that should not be overlooked. In particular, this information helps to interpret the data and make better 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 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: the possibility of exporting in the future might 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 to 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 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 more the innovation. Thus, the model generates positive relationship between size and productivity. Since larger trade costs difficult the 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 small (less productive) firms because of large innovation costs, large trade costs, or both.

Exporters grow at a constant rate. Acemoglu and Cao (2010) and Luttmer (2007, 2010) find similar 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 size, and equals the rate of growth of exporters at the export

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

threshold. Intuitively, the closer they 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, the estimates of innovation costs are biased downwards and the bias greatly differs across countries, potentially altering the open economy ranking. Second, the closed economy overpredicts the effects of changing innovation costs on welfare and aggregate productivity.

The downward bias of the estimates is because trade increases the incentives to innovate, so to match the same target, the costs must be larger in the open economy. We decompose the relative bias between two countries into the difference in innovation costs under the open economy assumption and the different incentives faced by exporters and non exporters.

The closed economy model amplifies the reaction to an increase in innovation costs. The reason is that exporters are less exposed to them. Such an increase reduces innovation, profits, and consequently income and demand, which further reduces profits and innovation. In the open economy, firms shift output towards exports, milding down these effects. We show analytically that larger innovation costs increases the exports to sales ratio of exporters.

We next study the quantitative importance of this problem. We calibrate the model economy to a set of European countries using the European Firms in a Global Economy (EFIGE) database. This contains detailed, comparable information on manufacturing firms with more than nine employees. We focus on Germany, U.K., Italy, France and Spain. Given the sample of countries, our estimates do not capture self imposed trade barriers such as tariffs. We capture a more general kind 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 do not necessarily relate to trade between countries, but 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. Further, the full characterization of the firm's dynamics provides a direct mapping between growth rates and each of the frictions. Thus, we reverse-engineer the innovation cost 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 and across steady states, reacts by between 31 percent (Italy) and 64 percent (France) more in the closed economy when innovation costs change by one percent. The reason is that exporters suffer less the impact of larger domestic innovation costs by shifting production towards exports.

The difference in the estimation of the innovation costs is also large. 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 larger than Germany's. Under the closed economy, this drops to 12 percent. Low export costs mask large domestic distortions. By ignoring data on exports, the closed economy is assuming that Italy's barriers to firm growth are not as bad, and is missing the fact that Italians are great at exporting.

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

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

A novel result is that lower trade barriers increases incentives for non exporters to innovate. As firms approach their export threshold, they speed up growth. Moreover, a drop 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 to Korean data. In their paper, a reduction in export costs increases R&D of both exporters and non exporters. This is a theoretical prediction of our framework.

This result provides a new interpretation to an old observation: firms start growing faster *before* they become exporters. This led Bernard and Jensen (1999) to conclude trade barriers are not likely to affect firm productivity because productivity grows before firms export. Our model suggests that trade liberalization increases growth of non exporting firms that hope to export in the future. This result is useful for papers that use non exporters as a control group during trade liberalizations, such as Van Biesebroeck (2005) and De Loecker (2007).

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 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.

The strong interdepence 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. Trefler (2004) shows that Canadian productivity increased when tariffs dropped, and Rubini (2011) 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.

We are related to Bhattacharya et al. (2011), who use a model with endogenous innovation to identify resource misallocation in a closed economy framework. Impulitti et. al. (*forthcoming*) 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.

We abstract from an important channel linking innovation and imports. 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. Section 5 evaluates the model against non targeted dimensions. Sections 6 and 7 show the main results of the paper. 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.[3]

[2] Griffith et al. (2006) show that many U.K. firms perform their R&D activities abroad, mainly in the U.S.
[3] We also assumed a world with only the countries in our sample and the results are very similar.

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 at time t and the rest of the world 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 each period that make production, innovation, and exporting decisions. Firms die instantly with an exogenous probability $\delta \in (0,1)$. They are owned by the domestic consumer who receives lump sum their profits. Each firm is a monopolist. Given a productivity 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,

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

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

Exporting requires a once and for all sunk cost of κ_{xj} units of labor. 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.[5]

[4] A preference parameter in the technology follows Atkeson and Burstein (2010) and simpllifies the algebra.
[5] The reason for this is that we could not calibrate entry costs per country.

Labor Market Clearing.

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

where $M_j(t)$ is the measure of entrants in country j at time t, L_j 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, 0 otherwise.

Trade Balance.

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

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 profits of a firm ω. A * denotes 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

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

Firms solve a static problem and a dynamic problem. The static problem is how much to produce and the price given their current productivity, and the dynamic problem is how much to innovate and, for non exporters, whether to become exporters. For domestic customers,

$$\max_{p,q,n} \quad pq - w_j n \qquad s.t. \qquad q = z(\omega)^{\frac{1}{\sigma-1}} n = p^{-\sigma} P_j^{\sigma-1} I_j$$

For foreign customers

$$\max_{p,q,n} \quad (1+\tau_{xj})pq - w_j n \quad s.t. \qquad q = \frac{z(\omega)^{\frac{1}{\sigma-1}} n}{(1+\tau_{xj})} = (1+\tau_{xj} p)^{-\sigma} P_j^{\sigma-1} I_j$$

The solution to these problems is the mark-up rule $p_j(\omega) = \frac{\sigma}{\sigma-1} w_j z(\omega)^{\frac{-1}{\sigma-1}}$. Let $\hat{\pi}_{dj}(P, I, z)$ be the variable profits for a non exporter (profits before paying innovation or exporting costs) and $\hat{\pi}_{xj}(P, I, z)$ 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 on when to become exporters and how much to innovate[6]. Let z_{xj} be the optimal size at which firms become exporters. Their

[6]It is straightforward to show that a non exporter will always choose to become an exporter if it survives long enough. Simply calculate its value given that it never exports and show that, for a sufficiently large z, the value of becoming an exporter exceeds the value of continuing as a non exporter.

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 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

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

2.2 Characterizing the Steady State

Exporters. To solve the exporter problem, we guess and verify 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

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

Thhis 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

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

[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 generate loses every period and therefore cannot be the optimal.

Introducing the solution in the Bellman equation

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

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 the 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 implicity solution for non exporter's growth rate.[8] Proposition 1 shows how trade barriers affect the non exporting sector.

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 $g_d(z_x) = g_x$ implies (iii). So we only need to prove (i) and (ii). To see (ii), first notice 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

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

[8] See footnote 9 for more details on the the implicity solution.

Using the envelope theorem shows the result (notice 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 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, notice 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 $\partial g_d(z)/\partial\tau_x < 0 \Rightarrow g_1 < g_d(z)$ for all $z \in [1, z_x]$. Also notice 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 $g_d'(z) > 0$. □

The intuition behind proposition 1 is the following. The possibility of future exports represents an option value for the firm. Its value depends on how likely it will become an exporter (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, and, through equation (14), $g_d(z)$ increasing). In turn, the option value is increasing in exporting profits. Larger trade costs reduce those profits and therefore innovation and growth rates of non exporters. Similarly, a larger sunk export cost increases the threshold z_x, making exporting more distant and harder to achieve, reducing the option value, and innovation itself. Thus, policies that affect the exporting sector have a direct effect through the firm's 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 doing so. This is consistent with what Bernard and Jensen (1999) find for U.S. firms. Based on it, they conclude that firms became better for reasons other than exporting, and they 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 measuring 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 non exporters are also affected by trade barriers.

The firm size distribution. A problem with the solution of equation (15) is that it has no closed form solution. We approximate the solution 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. This functional form allows for a closed form distribution of firms in equilibrium. In the quantitative section we choose the parameters to approximate the real solution and we show that the fit is very good.[9] The steady state distribution is[10]

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

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

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

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

[9] 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 close by a polynomial.

[10] See the online Appendix A, https://sites.google.com/a/asu.edu/loris-rubini/Appendices.pdf?attredirects=0

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 pin down 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 workers, where output is defined as the CES aggregate good (Q_j in equation (1)). We show in the online Appendix B[11] 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 $\mu_j(z) = M_j z^{-\delta/g_j}$.

[11] https://sites.google.com/a/asu.edu/loris-rubini/Appendices.pdf?attredirects=0

3 Open vs. Closed Economies

We next compare two types of results of the open and closed economy assumptions. The first relates to the estimates of innovation costs. We show that the closed economy produces lower estimates of innovation costs. The difference arises because the closed economy cannot capture the innovation incentives associated with exporting. We show that exporting not only increases the innovation of exporters, but also of non exporters who anticipate becoming exporters in the future.

The second result compares the effect of increasing an innovation cost on welfare. The closed economy always exaggerates the welfare loss. We show analytically that when faced with larger domestic innovation costs, exporters shift sales towards the export market. The reason is that higher innovation costs reduce profits, which reduces domestic income, and this reduces 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. By ignoring data on export behavior, something is lost. This section derives analytical results to understand what exactly is lost and how it affects estimates and counterfacturals. Section 6 shows the magnitude of these difference 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 the open and the closed economies. Large firms are the exporters in the open economy, and 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 efficiency ranking among countries 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: Using equation (15) evaluated at $z = 1$ and using the free entry condition,

$$\rho w_j \kappa_e = \pi_{jj} + \frac{\kappa_{I,j} g_{dj}(1)^2}{2}$$

Introducing the above equation in the definition of profits for exporters we obtain

$$\pi_{xj} = \rho w_j \kappa_e - \frac{\kappa_{Ij} g_{dj}(1)^2}{2} + (1+\tau_{xj})^{1-\sigma} \left(\frac{w_j}{w^*}\right)^{1-\sigma} \pi_d^*$$

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

where $D_j = 1 + \tau_{xj}$. Because of the exporters optimal innovation policy:

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

The implied innovation cost in the closed economy, κ_j^c, must satisfy:

$$1 - \left(1 - \frac{\kappa_e}{\rho \kappa^d}\right)^2 = 1 - \left(1 - \frac{g_{x1}}{\rho}\right)^2$$

Introducing the last expression in equation (22) and simplifying,

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

From free entry in the closed economy, $g_{xj} = \frac{\kappa_e}{\kappa_j^c}$, so

$$2\kappa_e(\rho+\delta)\left[\frac{1}{\kappa_j^c} - \frac{1}{\kappa_{Ij}}\right] = g_{xj}^2 - g_{dj}(1)^2 + \frac{2\pi_d^*}{\kappa_{Ij} w_j} \left(D_j \frac{w_j}{w^*}\right)^{1-\sigma} \tag{23}$$

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 $\kappa_j^c < \kappa_{Ij}$. □

Thus, the closed economy underestimates innovation costs. The intuition is that trade adds innovation incentives. If incentives are larger, the calibration requires larger costs to generate the same slope of the distribution of firms. The closed economy assumption generates estimates of the domestic innovation costs that are always biased downwards. We show in the quantitative section this effect is actually sizeable.

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 costs 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 would never expect to export.*

Proof: See the online Appendix C.

The growth rate $\tilde{g}_i$ is the growth rate attributed solely to the domestic market. Thus, $g_{di} - \tilde{g}_i$ is the extra growth because of the export incentives for non exporters. 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 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[12] $(g_{xi} - \tilde{g}_i)$. 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 fact that $g_{di}(1) > \tilde{g}_i$ implies that firms invest to export.[13]

A result that follows from the Corollary is that when ranking countries according to their innovation cost, this ranking 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 actually happens for some countries.

[12] 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.

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

3.2 Counterfactuals

In this section we show that, for a special case, the closed economy over predicts the effects of counterfactuals on productivity and welfare. This special case assumes that $\kappa_x = 0$ for all countries, so all firms export, and $\sigma \leq 3/2$. These are sufficient conditions that simplify the algebra considerably, and allows us to make strong theoretical statements about the effects of changing innovation costs.

The intuition for this result is the following. Consider an increase in the domestic κ_I. On the one hand, this drives firms to reduce innovation, reducing aggregate productivity and welfare. On the other, associated to the increase in κ_I there 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 weight of exports on total sales, therefore 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 in this section, the over predictions of counterfactuals in the closed economy. An argument similar to that 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 shows clearly the effect of a change in innovation costs on firm growth rates, that is, $\frac{\partial g_x}{\partial \kappa_I} = -\frac{\kappa_e}{\kappa_I^2}$. This allows us to 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 pins down 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 normalize $L = 1$ and notice that 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 by its value in equilibrium shows

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

Next define Z_x as the productivity in the open economy and Z_c as the analogous under the closed economy assumption. The next 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 analogous 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 economy to match the same distribution of firms in equilibrium, it follows that $\mu_c(z) = \mu(z)$ for all z, and $\int_1^\infty z\mu(z)dz = \int_1^\infty z\mu_c(z)dz = Z_c$.$\square$

Notice the intuition behind 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 via 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 *If* $\sigma < 3/2$[14]*, a change in* κ_I *has a larger effect in the closed economy than in the open economy.*

[14] $\sigma < 3/2$ is a sufficient condition which we need to prove the proposition, but it is far from necessary. We found quantitatively this statement is true for many values of σ using numerical methods. The reason why a small σ is needed is that this increases the returns to scale in the economy, and the larger the gains from trade. In the extreme case where $\sigma = \infty$, there are no gains from trade.

Proof: The full proof is in the online Appendix D[15]. Intuitively, we first show $Z_x = Z_c \frac{\pi_x}{\pi_d}$. The proposition shows that when κ_I increases, Z_c falls, Z_x falls, but π_x/π_d increases, so the change in Z_c is larger than the change in Z_x.

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 in seven European countries: Austria, France, Germany, Hungary, Italy, Spain, and U.K. We do not include Austria and Hungary in the analysis, since these samples are too small. A policy report for the Bruegel Institute, Rubini et al. (2012) performs a similar analysis to this paper including all seven countries.

The database contains around 15,000 firms. 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 these activities are not modeled in this paper.[16]

We first document large differences in employee-size distributions across the European countries. France, Germany, and 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[17], an observation that is consistent with Tybout (2000), who surveyed the literature studying firm size distributions 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 excludes firms with more than 10,000 employees. The x-axis plots the log of employees, and the y-axis 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 given sizes decreases: a steeper slope implies 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 implies very few firms in some industries). Also, the estimation is robust to different minimum employee thresholds.

[15] `https://sites.google.com/a/asu.edu/loris-rubini/Appendices.pdf?attredirects=0`

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

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

One determinant that is highly relevant is export status. Figure 2 shows the distribution excluding non exporters. At first sight, 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 now is mixed with France and U.K. Germany has the flattest distribution. Thus, trade costs are important in accounting for the difference in distributions.

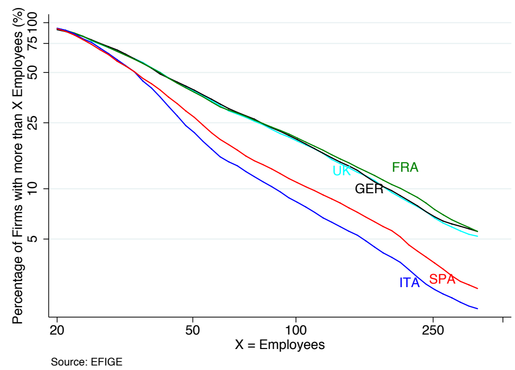


Figure 1: Firm Size Distributions

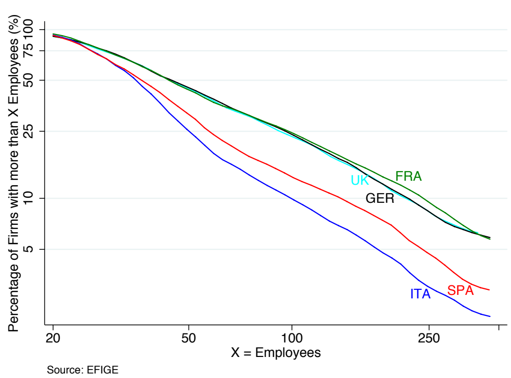


Figure 2: Exporters' Distributions

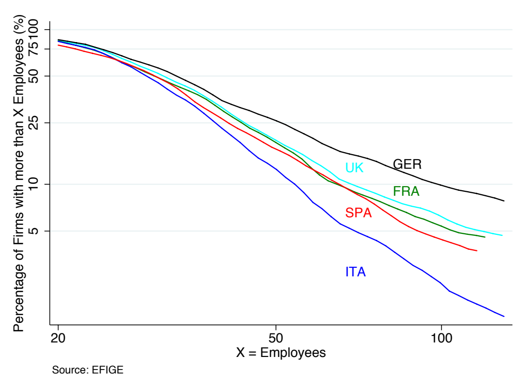


Figure 3: Non-exporters' Distributions

4.2 Calibration

We set the total number of countries equal to 5 to represent France, Germany, Italy, Spain and U.K. This leaves out Austria and Hungary. We have excluded these countries because the sample is smaller and less reliable in terms of representativeness[18]. On this note, Rubini et al. (2012) incorporates these countries and the results hardly change.

We introduce labor and corporate taxes into the analysis. Labor taxes from McDaniel (2007) using the 2007- 2009 average. Labor taxes 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 taxes 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. We assume innovation cannot be deducted from taxes.

A problem is how to calibrate the rest of the world. As it turns out, if we normalize the iceberg trade cost for one country, we do not need to calibrate the rest of the world (setting $\tau_{xj}=0$ for some country j is the same as calibrating the size of the rest of the world). Thus, our calibrated iceberg costs are subject to the normalization that we choose. We normalize $\tau_{x,GER}=0$. This does not affect the ratio $\frac{1+\tau_{xj}}{1+\tau_{x,GER}}$. We next describe the calibration strategy, and after the calibration targets.

4.3 Calibration Strategy

On general lines, the calibration strategy is the following. We calibrate the following parameters independently: tax rates, size of the economy and death rates. 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 exactly pinned down 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. We first pin down from the slope of the firm size distribution 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

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

[18] We know it is less representative after discussing with people at the European Commission in charge of collecting the data.

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) this 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. This 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, the 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} that make equations (24),(25) and (26) hold in equilibrium.

Rest of the world. So far we 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 calibrate are therefore $\pi_d^*/(w^*(1+\tau_l^*))$ and $X^* = (1+\tau_x^*)^{1-\sigma}((1+\tau_l^*)w^*)^{1-\sigma}\int_{z_x^*}^{\infty} z\mu^*(dz)$. The first thing to notice is 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 the trade costs of every country 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 $\frac{\pi_d^*}{(1+\tau_l^*)w^*}$. In this way, we are identifying the iceberg cost in country j relative to Germany's iceberg cost.

We proceed similarly to calibrate the supply from the rest of the world. We use this to find the 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 analogous 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 $\mu_j(z), \mu_{GER}(z)$. This pins 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}. These are four parameters per country. We use four targets from the EFIGE database. We 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[19].
- The share of firms that export

[19]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. This is problematic since firms do not report their sales. They do report the number of employees and the share of output exported. 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 the non exporter growth rates. In the online Appendix E[20] we show the values for the fitted parameters. We also compare the numerical solution together with the approximation for the growth rates and value functions. Figures E.1 through E.5 in online Appendix E show that, for most cases, the approximation is indistinguishable from the numerical solution.

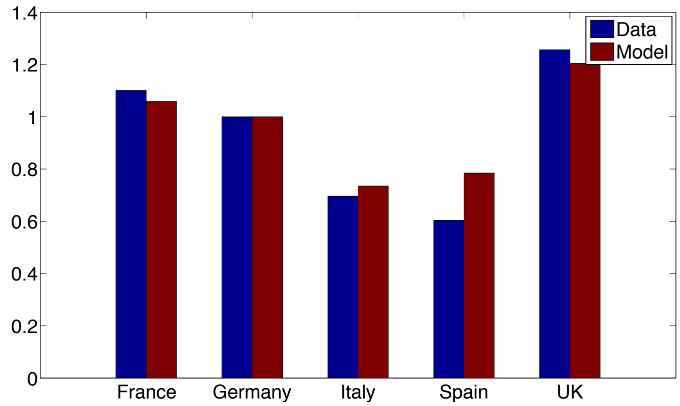
5 The Model Along Non Targeted Dimensions

5.1 Value Added Per Worker: Model vs. Data

Value added per worker in the data is from Eurostat, averaging years 2004 through 2010. The model performs exceptionally well. Figure 4 shows this comparison. The model can account for a large fraction of the differences in value added per worker in the manufacturing sector in these economies. Table 2 compares the value added per worker in the data with the model. The model can account for between 54 and 87 percent of the differences in value added per worker. It is worth mentioning that the accounting of the closed economy model would be

[20] https://sites.google.com/a/asu.edu/loris-rubini/Appendices.pdf?attredirects=0

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



very similar, except that the closed economy would put the blame entirely on innovation cost differences, ignoring the effect of trade barriers.

Table 2: 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%

5.2 Wages: Model vs. Data

Next we turn to comparing wages in the model and the data. We use data from Eurostat, for the year 2006, since the year 2008 did not include data for U.K. We compare the wages in the model with the mean hourly wage relative to Germany in the data. Figure 5 shows this comparison. The model does a good job at generating the wage differences we observe in the data.

Figure 5: Mean Hourly Wages (Germany = 1)

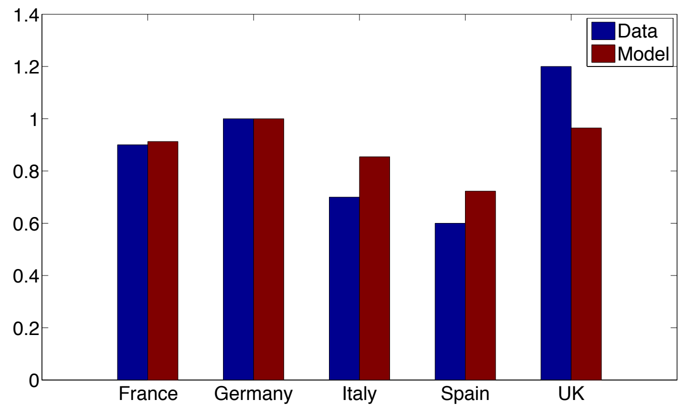
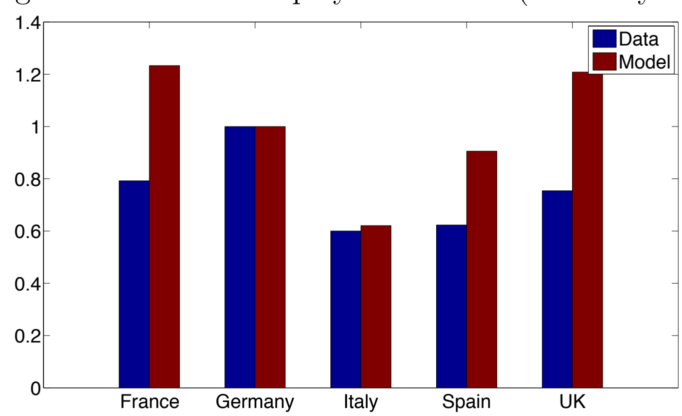


Figure 6: Share of Employees in R&D (Germany = 1)



5.3 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 the relative levels for the other countries. We ignore missing information observations for our comparison.

The model performs particularly well for Italy. In Spain, France and U.K. it predicts too many employees will go into R&D. U.K. has a relatively low level of R&D when comparing 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, especially in the United States, as documented by Griffith et al. (2006).

6 Quantitative Results

Table 3 shows the values for the calibration of the key parameters and the implied exporter growth rates. We normalize costs so that they equal 1 in Germany.

Table 3: 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 flattness is consistent with the low rates of growth we identify. Italy's low growth rates are mainly because innovation is expensive: 33% more expensive than in Germany. Spain, on the other hand, has a hard time exporting: it costs 43% more than in Germany.

We can learn also from the behavior of the remaining countries. Notice that France has higher costs than Germany, particularly higher sunk export costs, and still their exporters grow faster. The larger sunk export costs acts as a barrier to entry in the export market, which reduces competition, and so insiders enjoy larger profits and thus innovate more, growing faster.[21] U.K. exporters grow fast because the sunk export costs are larger, and the variable trade costs are lower than in Germany. This more than compensates a slightly larger cost of innovation, resulting in a larger growth rate.

Before moving any further, we try to understand the magnitude of these estimates. We focus on innovation costs and iceberg costs. Innovation costs have to do with how easy it is for firms to grow. Our estimates suggest that it is much costlier to grow in Italy than in any

[21]Notice that this is a general equilibrium effect. As we noted in Proposition 1, the partial equilibrium effect is that a larger trade cost (fixed or variable) reduces the growth rate.

other country in the sample. The World Bank estimates how easy it is to do business in each country, based on a number of costs such as dealing with construction permits, registering property, getting credit, and enforcing contracts. Based on these (and more) categories, they prepare a general ranking. Table 4 reports the ranking of each country in the sample, together with our estimate for innovation costs.

Table 4: 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
United Kingdom	6	1.02

Source: http://www.doingbusiness.org

The order of both the World Bank ranking and our estimates are quite similar. 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 estimates of innovation costs.

Next we turn to iceberg costs. Waugh (2010) estimates trade costs for many countries. His list includes all the countries we have except Germany. Table 5 shows his estimates of trade costs relative to France for the four countries we have in common, and ours. In both estimates Spanish trade costs are the highest, although our differences are larger than his.

Table 5: Waugh's Trade Cost Estimates

Country	Waugh's	$1 + \tau_x$
UK	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 large export costs is the fact that their customers are farther away than the other countries', and this naturally requires larger transport costs. The EFIGE dataset includes information on where the products are shipped. Table 6 reports the share of exports within Europe, to North America, and to South and Central America. The farthest place is South and Central America, and the country exporting the most to South and Central America is Spain.

Table 6: 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%
UK	67%	12%	1%

Source: EFIGE

Finally, the World Bank reports measures of export costs. This measures are of reference when we compare countries that choose similar export methods. This is the case of Italy and Spain, two Peninsulas, with a natural advantage in maritime exports. The World Bank reports two big differences that increase export costs in Spain relative to Italy: (i) Spanish exports require 50% more paperwork than Italian (an average of 4 documents in Italy vs. 6 in Spain); and (ii) Spanish goods take 50% more days from the time they leave the factory until they reach the port of departure (2.6 in Italy vs. 4 in Spain). This last point may well be due to geography. While both countries are Peninsulas, Italy is a relatively thin area of land surrounded by water, while Spain is not so thin. This translates into 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 there is only one large port in Barcelona. Italy has five major ports, in Genoa, La Spezia, Livorno, Venice, and Napoli.[22]

7 Open vs. Closed Economies

In this section, we compare our results with a closed economy model. This is the type of model most of the literature focuses on, so our results can provide guidance as to how the predictions

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

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 innovation investments.

7.1 Estimates of Innovation Costs

Proposition 2 states that the closed economy underestimates the 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 equal to one, and express every other cost in terms of it. The second column shows, in absolute terms, the biased implied by assuming the economy is closed. In the third column, we express the innovation costs in the closed economy relative to Germany, to see clearly how the countries costs rank and compare them with the open economy.

Table 7: Innovation Cost: Closed vs. Open Economies

	Open (GER = 1)	$\frac{\text{Closed}}{\text{Open}}$	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 of 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 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 Germany under the closed economy assumption.

Corollary 3 gives some intuition as to why the bias might be different across countries. Mainly, Corollary 3 states that the bias will be larger when (i) the difference in actual costs is large; (ii) when the difference in exporter growth rates is large; and (iii) when the difference in the growth rates of entrants is large. Comparing Italy with Germany, we already concluded that (i) and (ii) are true, accounting for the large bias.

Table 8: Entrant Growth Rates and Variable g_1

	$g_d(1)$	g_1
France	2.23	1.95
Germany	2.23	2.11
Italy	2.02	1.54
Spain	2.41	1.98
U.K	2.33	2.04

On 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 too bad for these countries. In Germany, because the domestic economy is large enough to make the rest of the world less important. In Spain, because of its large export costs.

In terms of Corollary 3, while the exporter growth rates are different in these countries, the entrant growth rate is actually larger in Spain. This compensates for the difference in 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 the high export costs.[23] However, these large trade costs reduce the incentives to innovate, and firm innovation does not grow too much.

It is also interesting to compare Spain with France. Under the open economy model, they both have similar innovation costs, but France's cost drops by almost 10 percentage points under the closed economy model, while Spain's remains 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 under the open economy. We needed to make some assumptions to prove the theoretical results, and these are not met in the quantitative section (for example, no fixed export costs). In this

[23]Through trade balance, if a country exports little, it must also import little.

section, we show that in the calibrated model, the closed economy also amplifies the response to counterfactuals. Table 9 shows the elasticity of productivity with respect to a change in innovation costs for each country, and compares the closed and open economy predictions. We increase innovation costs by 0.5% and report elasticities. The closed economy estimates an elasticity between 43 and 73 percent larger than the open economy. These differences are similar for welfare, as we show in Table 10.

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

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

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

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

As proposition 4 suggests, the reason why productivity in the closed economy model reacts more than in the open economy is that 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 under the calibrated innovation costs, and when these costs increase by five percent. The results show that 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 to a change in trade costs, both exporters and non exporters. 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 by exporters. While the proposition is for 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, and the y-axis the growth rate. The numbers in the x-axis show the export thresholds and the numbers in the y-axis the 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 reducing the threshold z_x. This holds for every country.

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): by structurally calibrating a model of trade

Figure 7: French Growth Rates

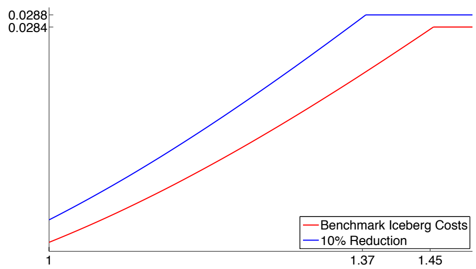


Figure 8: German Growth Rates

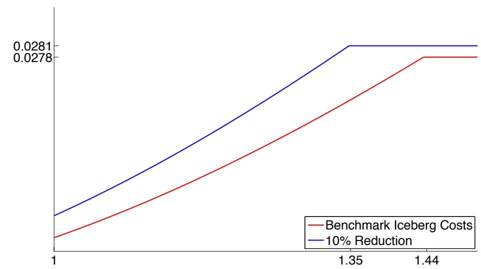


Figure 9: Italian Growth Rates

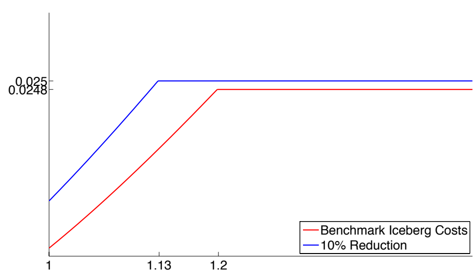
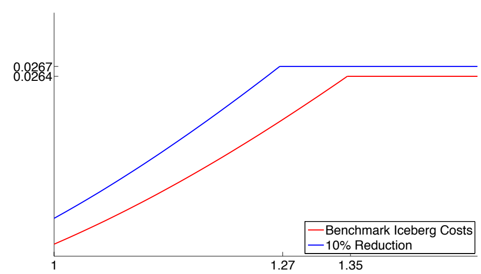


Figure 10: Spanish Growth Rates



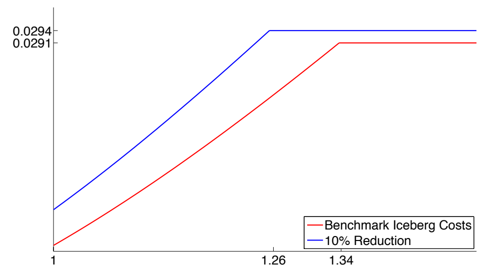
with R&D, they find that a reduction in trade costs increases the R&D of non exporters.

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 growth rates accelerating after entering 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 suggests that we should be careful when selecting a control group to study the effects of trade barriers. Non exporters are indeed affected by trade barriers, and this should be taken into account in papers that use these firms as control, such as Van Biesebroeck (2005) and De Loecker (2007).

Next we consider aggregate effects of changing trade costs. Atkeson and Burstein (2010) show that adding innovation into a model of trade does not change considerably the gains from

Figure 11: UK Growth Rates



reducing iceberg trade costs. We confirm their results by proceeding as Atkeson and Burstein (2010). We simulate a reduction in trade costs, and report the elasticity of productivity. We compare these numbers with those of a model with no innovation or fixed export costs, where we obtain the elasticity in closed form solution. We recalibrate this economy so that the trade volumes are as in the benchmark model. We report these numbers 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 asks whether adding 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 them to gain tractability.

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

In particular, when analyzing the distribution of firms in Europe, a model of closed economy would conclude that innovation costs in Italy are a less important problem that what the open economy model suggests. Moreover, the closed economy model fails to identify the area where Italians excell: exporting. Also, the closed economy model would predict that changes that affect domestic innovation costs have too much of an effect 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 on 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 behaviour is not exogenous: both exporters and non exporters react to a change in trade costs. One prediction 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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