Complementarity, Linkages between Firms, and the Effect of Entry Costs on Productivity

Fernando del Rio and Antonio Sampayo

Departamento de Fundamentos da Análise Económica. Universidade de Santiago de Compostela, Spain.

Abstract

In a general equilibrium model where firms are heteroge-neous in terms of productivity, we introduce differenti-ated goods in production that are not perfect substitutes, as well as intermediate inputs needed to produce those goods. We show that an increase in either the comple-mentarity of differentiated goods or the share of interme-diate inputs in gross output, significantly increases the negative effect of entry costs on total factor productivity (TFP) and output per worker. We also find that the effect of complementarity is quantitatively stronger. If we assume an empirically plausible value for the elasticity of substitution between differentiated goods, then the model considerably improves its ability to reproduce the observed negative relationship between entry costs and TFP or output per worker.

1 INTRODUCTION

The ease of starting a new business differs significantly from one country to the next. In 2012, the cost of following the procedures required to start up a firm was 0.3% of annual per capita income in New Zealand (the least expensive country); in Chad (the most expensive country), the corresponding figure was 186.3%. The worldwide average was 31.7% of annual per capita income.[1]

There is empirical evidence on the significant negative effect of entry costs on gross domestic product (GDP) per worker and on total factor productivity (TFP). In particular, Barseghyan (2008)

*The authors gratefully acknowledge financial support from Xunta de Galicia research program GPC2013-045 partly funded the European Regional Development Fund (ERDF), as well as from the Spanish Ministry of Economy and Competitiveness research program ECO2013-48884-C3-1-P.

estimates a negative impact of entry costs on both GDP per worker and TFP. His regressions also show that entry costs have no statistically significant effect on human capital or on the capital–output ratio. Loayza, Oviedo, and Servén (2005) carry out an empirical analysis while controlling for the likely endogeneity of regulation with respect to macroeconomic performance; they conclude that a stronger regulatory burden reduces growth and also increases its volatility. Nicoletti and Scarpetta (2003) analyze the empirical link between regulation and productivity, concluding that market-friendly regulatory reforms boost productivity growth.

The importance for economic development of linkages (and complementarity) between sectors through intermediate inputs must be recognized. As pointed out by Jones (2011), the notion that linkages across sectors can be central to economic performance dates back at least to Leontief (1936). Hirschman (1958) also emphasized the importance of linkages (and complementarity) for economic development. According to the empirical evidence reported by Jones (2011) for a sample of 35 countries (all of them OECD members except for Argentina, Brazil, China, India, Indonesia, and Russia), the share of intermediate inputs in gross output ranges from a minimum of 38% for Greece to a maximum of 63% for China; the average is 52.6%, with a standard deviation of 6%.[2] Empirical evidence reveals a significant variation in the share of intermediate inputs across countries. However, there is no apparent correlation between this share and per capita GDP across countries.[3]

The aim of this paper is to analyze the potential role played by links and complementarity across firms in amplifying the quantitative effects of entry costs on TFP and GDP per worker. To that end, we develop a general equilibrium model with productivity heterogeneity between firms along the lines of Hopenhayn (1992), Hopenhayn and Rogerson (1993) or Atkeson and Kehoe (2005). The distinctive feature of our model is that we allow for linkages and complementarity in production, along the lines set out by Jones (2011, 2013). Firms producing intermediate inputs are *ex ante* identical and face a sunk entry cost. Once this entry cost is paid, the firm receives an independent and identically distributed productivity shock that remains constant after entry as in Melitz (2003). Firms also incur fixed operating costs in terms of overhead labor as in Poschke (2010) and Barseghyan and DiCecio (2011). In this framework with free entry, a higher entry cost implies that entry will continue to occur if wages are lower. These lower wages allow less productive firms to be in the market so that the average productivity of firms and also TFP are smaller than in the case of a lower entry cost.

We incorporate intermediate inputs and complementary differentiated goods in order to capture the significance of links and complementarities between firms in accounting for differences in productivity. As noted above, Jones (2011) argues that links across sectors and firms are key to a country's economic performance given that such links tend to amplify the effects that distortionary policies have on aggregate productivity – because of a "multiplier effect" similar to the one associated with capital in the neoclassical model. Thus, inefficiencies that originate in one sector can propagate across the economy; in turn, this can further reduce productivity in the original sector. As Jones states: "Low productivity in electric power generation – for example, because of theft, inferior technology, or misallocation – makes electricity more costly, which reduces output in banking and construction. But this in turn makes it harder to finance and build new dams and therefore further hinders electric power generation." Complementarities in production are also crucial to any analysis of the consequences of links across sectors because greater complementarity places extra weight on lower-productivity sectors. As illustrated by the O-ring story in Kremer (1993), higher levels of complementarity entail that sectors with lower productivity have a greater effect on aggregate productivity.

Using this framework, we can show that a decrease in the elasticity of substitution of differentiated goods or an increase in the intermediate inputs share significantly amplifies the negative effect of entry costs on aggregate productivity. Assume that the relationship between the logs of entry costs and productivity is linear, which is nearly the case in our model. The slope of this relationship increases when the elasticity of substitution decreases or the share of intermediate inputs increases, holding all other parameters constant. In particular, an increase of 1% in the entry costs reduces TFP by 0.15% if the elasticity of substitution is infinity, by 0.42% if the elasticity of substitution is 5 (which is roughly consistent with the average of the estimates provided by Broda & Weinstein, 2006, for the United States), and by 0.76% if the elasticity of substitution is 2 (which is in accordance with the median of the estimates provided by Broda & Weinstein, 2006).[4] On the other hand, an increase of 1% in the entry costs reduces TFP by 0.38%, 0.42% and 0.50% if the share of intermediate inputs is, respectively, 38% (which is the minimum value in the OECD cross-country sample), 46% (which is the US value), and 63% (the maximum value in the OECD cross-country sample). Therefore, at least for reasonable values of the parameters, changes in the intermediate inputs share have a lower impact on the relationship between productivity and entry costs than changes in the elasticity of substitution.

Moreover, if we do *not* assume perfect substitution between intermediate inputs, then the empirical performance of our model improves significantly. The model can accurately reproduce the empirical evidence reported by Barseghyan (2008) on the relationship (across countries) between entry costs and both GDP per worker and TFP, whenever an empirically plausible value for the elasticity of substitution between intermediate inputs is assumed. He finds that an increase of entry costs by 80% of income per capita decreases output per worker and TFP by 29% and 22%, respectively. In our model, if the elasticity of substitution is 5 then increasing entry costs by 80% of output per worker reduces GDP per worker and TFP by 50% and 34%, respectively. A value of the elasticity of substitution around 10 allows us to obtain Barseghyan's (2008) estimates in our simulations. If inputs are perfect substitutes, then our model implies that an increase in entry costs by 80% of output per worker reduces GDP per worker and TFP by 17% and 11%, respectively. We also show TFP differences between countries that exhibit the highest and lowest entry costs. If the elasticity of substitution is infinity then the model accounts for 20% (33%) of the observed ratio between the first and tenth (fourth) TFP decile (quartile), while if the elasticity of substitution is 5 then the model accounts for 33% (45%) of the observed ratio.

The basic mechanism driving our results, which is also present in the literature mentioned above, is that a decrease in entry costs provokes an increase in average aggregate productivity because firms, as explained above, have to pay higher wages. As a consequence some firms at the lower end of the productivity distribution become unprofitable and leave the industry, as a result of which employment is concentrated in more productive firms. However, the distinctive feature of our model is that the productivity gains of this reallocation are larger, the higher is the complementarity between differentiated goods. In equilibrium, the wage rate is determined by the marginal productivity of labor of the marginal firm (the firm that is indifferent between leaving the industry or not) that constitutes the exit productivity threshold. If differentiated goods were perfect substitutes, the marginal productivity of labor of the marginal firm would be entirely idiosyncratic. However, when intermediate goods exhibit some degree of complementarity, it depends less on the marginal idiosyncratic productivity and more on the average aggregate productivity. This is the way in which complementarity affects the change in the productivity of the marginal firm needed to adjust the wage rate. While the final effect on aggregate productivity is unclear, we will show that, for a reasonable calibration, our model quantitatively displays a bigger negative impact of entry costs on TFP, when differentiated goods are not perfect substitutes.

Several studies have analyzed the role of distorted resource allocation across firms to understand productivity differences across countries. Hsieh and Klenow (2009) and Restuccia and Rogerson (2008), analyze how the costs of reallocation affect aggregate TFP. In these studies, the barriers are hypothetically given in the model (Restuccia & Rogerson, 2008) or measured as "wedges" compared to the frictionless allocation (Hsieh & Klenow, 2009). Like Barseghyan and DiCecio (2011) and Moscoso-Boedo and Mukoyama (2012), we utilize the direct measures of these barriers from the World Bank's "Doing Business" dataset. Marimon and Quadrini (2006) argue that higher entry costs can account for cross-country income differences by discouraging human capital accumulation. Poschke (2010) shows that a model with technology choice and product differentiation exhibits a large effect of entry costs on productivity. Barseghyan and DiCecio (2011) and Moscoso-Boedo and Mukoyama (2012) develop general equilibrium industry-dynamic models along the lines of the model developed here in order to evaluate the effects of entry costs on cross-country productivity differences.[5] However, they do no take into account the existence of linkages and complementarities between firms via differentiated goods and intermediate inputs. Donovan (2014) considers intermediate inputs in production and analyses how some agriculture-specific distortions influence the share of intermediate inputs, which can help to account for differences in productivity across countries.[6] Our paper adds to this list by exploring the extent to which a plausible mechanism (namely, the existence of links and complementarities between firms via differentiated goods and intermediate inputs) could amplify the effect on aggregate productivity of resource misallocation stemming from entry costs.

The rest of the paper is organized as follows. The model is described in Section 2. Simulation results are presented in Section 3. Section 4 concludes.

2 THE MODEL

2.1 Final Sector

A perfectly competitive representative firm produces both a final good and an intermediate input. The final good can be allocated to consumption and investment; the intermediate input is used to produce a continuum of differentiated goods. The representative firm uses a constant elasticity of substitution (CES) production function defined over a continuum of differentiated goods in the interval $[0,n]$.[7] Output of the final good and the intermediate input, $y+z$, is given by

$$y + z = n^{(\eta-1)/\eta}\left(\int_0^n x_i^{\eta}di\right)^{1/\eta}, \tag{1}$$

where $0<\eta\leq 1$, n is a measure of the firms engaged in production of differentiated goods, and x_i is the demand of the differentiated good i by the representative firm; here z and y are the amount produced of intermediate input and final good, respectively.

Production function (1) is intended to embody the reliance of goods manufacturing on a wide variety of specialized business services and goods as inputs. The parameter η provides a measure of the degree of "differentiation" between any pair of differentiated goods, since the elasticity of substitution between any pair is $1/(1-\eta)$. As pointed out by Jones (2011), $1/(1-\eta)$ (or its inverse) could also be termed the "elasticity of complementarity". As η approaches 1, the elasticity of substitution approaches ∞. Yet if η decreases, then the elasticity of substitution decreases and so the degree of complementarity between differentiated goods increases. A value of $\eta = 0.8$, which is empirically plausible as we will argue below, implies an elasticity of substitution of 5.

The perfectly competitive representative firm chooses x_i so as to maximize its profits subject to its technological constraint (1). The first-order condition of this firm's maximization problem is

$$p_i = \left(\frac{y+z}{nx_i}\right)^{1-\eta}, \tag{2}$$

for all $i \in [0,n]$, where p_i is the price of differentiated good i and where the price of the final good has been normalized to 1. The price of the intermediate input equals the price of the final good and is also 1. From (1) and (2) it follows that

$$\int_0^n p_i x_i di = y + z. \tag{3}$$

2.2 Intermediate Sector

Each differentiated good is produced by a perfectly competitive representative firm. A firm engaged in production incurs an operating cost consisting of wages paid to ϕ units of overhead labor. Thus, total overhead labor is ϕn. Each firm uses a Cobb–Douglas production function,

$$x_i = \left[q_i^{1-\alpha}\left(k_i^{\theta} l_i^{1-\theta}\right)^{\alpha}\right]^{1-\gamma} z_i^{\gamma}, \tag{4}$$

where $0<\theta<1$, $0<\alpha<1$, and $0<\gamma<1$ and where k_i and l_i are respectively the stock of capital and the variable number of workers used in the production of differentiated good i. Here q_i is productivity of intermediate firm i, and z_i is the amount of intermediate input used to produce the differentiated good i. The parameter α reflects the extent of decreasing internal returns to scale from both capital and labor. The parameter γ represents the share of the intermediate input in the gross output of firms producing differentiated goods. The intensity of links across sectors depends on γ. If $\gamma = 0$, then the productivity of labor and capital in each variety depends only on q_i and thus is independent of the rest of the economy. However, to the extent that $\gamma>0$, low productivity in one sector feeds back into the other sectors.

A firm producing the differentiated good i maximizes its profit,

$$\pi_i = p_i x_i - r_k k_i - w(l_i + \phi) - z_i, \tag{5}$$

subject to technological constraint (4). The first-order conditions for this profit-maximizing problem are

$$r_k = \alpha(1-\gamma)\theta \frac{p_i x_i}{k_i}, \tag{6}$$

$$w = \alpha(1-\gamma)(1-\theta)\frac{p_i x_i}{l_i}, \tag{7}$$

$$1 = \gamma \frac{p_i x_i}{z_i}, \tag{8}$$

for all $i \in [0,n]$, where w is the wage rate and r_k is the rental price of capital. Equations (6) and (7) establish that the marginal product of each factor is equal to the rental price. Equation (8) establishes that the marginal product of the intermediate input equals its price (which has been normalized to unity).

2.3 Aggregation

From (3) and (8) it follows that

$$z = \gamma(y + z), \tag{9}$$

where

$$z = \int_0^n z_i \mathrm{d}i$$

is the aggregate quantity of the intermediate input used in the production of differentiated goods and γ is the intermediate input share in gross output. Using (3) and (9), the first-order conditions (6) and (7) can be rewritten as

$$r_k = \alpha\theta \frac{y}{k} \tag{10}$$

and

$$w = \alpha(1 - \theta)\frac{y}{l}, \tag{11}$$

where

$$k = \int_0^n k_i di \quad \text{and} \quad l = \int_0^n l_i di$$

are respectively the aggregate quantities of capital and variable labor used in production. In equilibrium, labor supply (which it is normalized to unity) must be equal to total variable labor l plus total overhead labor ϕn:

$$1 = l + \phi n. \tag{12}$$

After some algebra (which is relegated to the Appendix), output of the final good can be rewritten as a function of TFP and aggregate capital as follows:

$$y = Ak^{\alpha\theta}. \tag{13}$$

Here

$$A = \left(\frac{1}{\phi}\right)^{1-\alpha} \left[(1-\gamma)^{1-\gamma}\gamma^{\gamma}\right]^{1/(1-\gamma)} q^{1-\alpha}(1-l)^{1-\alpha} l^{\alpha(1-\theta)} \tag{14}$$

is the TFP, which depends not only on the allocation of labor between productive and overhead uses but also on an average productivity index

$$q = \left(\frac{1}{n}\int_0^n q_i^{\Delta} \text{ d } i\right)^{1/\Delta}, \tag{15}$$

where

$$\Delta = \frac{(1-\alpha)(1-\gamma)\eta}{1 - \eta + (1-\alpha)(1-\gamma)\eta}. \tag{16}$$

Firm i's value added is equal to the average value added by the firm multiplied by a function of its relative productivity,

$$(1-\gamma)p_i x_i = \frac{y}{n}\left(\frac{q_i}{q}\right)^{\Delta}. \tag{17}$$

2.4 Entry

New firms deciding to enter the intermediate sector do not know their productivity, which is an independent realization of a random variable ε. This variable is distributed according to the function $F{:}R \longrightarrow [0,1]$, with positive density f on the support $[0,\infty)$ and where $\int_0^{\infty} \varepsilon f(\varepsilon)\mathrm{d}\varepsilon < \infty$. It is assumed that productivity remains constant throughout the firm's lifetime. Entry into the intermediate sector requires that the firm pay an entry fee equal to λy ($\lambda>0$) units of the final good.[8] The government collects firms' entry fees and redistributes them to households as a lump-sum transfer. Firms know their productivity after paying the entry costs.

Using equations (6)–(8) allows us to rewrite equation (5) as $\pi_i=(1-\gamma)(1-\alpha)p_i x_i - w\phi$. Substituting (11) and (17) into this expression, assuming that $q_i=\varepsilon$, and taking (12) into account, we have

$$\pi_\varepsilon = y\phi\left[(1-\alpha)\left(\frac{\varepsilon}{q}\right)^{\Delta}\frac{1}{1-l} - \alpha(1-\theta)\frac{1}{l}\right]. \tag{18}$$

From (18) it now follows that firm i's profits are an increasing function of its productivity. A new-entrant firm decides to start production if and only if $\pi_\varepsilon \geq 0$. For a stationary equilibrium in which y, l, and q are constant, a potential entrant deciding to start production never drops out thereafter; similarly, a potential entrant deciding to stay out never reverses that decision. Hence there is a minimum productivity level, $\underline{\varepsilon}$, for which

$$\pi_{\underline{\varepsilon}} = 0; \tag{19}$$

thus a new entrant does not start production for all $\varepsilon<\underline{\varepsilon}$ but does start production for all $\varepsilon \geq \underline{\varepsilon}$. Given equation (18), equation (19) implies that

$$\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta} = \frac{\alpha(1-\theta)}{1-\alpha}\frac{1-l}{l}. \tag{20}$$

Let $m(\varepsilon)$ be the density of firms with productivity ε that are engaged in production. In a stationary equilibrium, m is constant and is determined by the distribution of productivity (conditional on successful entry). Therefore, $m(\varepsilon)$ is the conditional distribution of $f(\varepsilon)$ on the interval $[\underline{\varepsilon},\infty)$ such that $m(\varepsilon)=f(\varepsilon)/(1-F(\underline{\varepsilon}))$ if $\varepsilon \geq \underline{\varepsilon}$ and $m(\varepsilon)=0$ otherwise. It follows that the average productivity index, q, can be rewritten as

$$q(\underline{\varepsilon}) = \left(\frac{1}{1-F(\underline{\varepsilon})}\int_{\underline{\varepsilon}}^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon\right)^{1/\Delta}. \tag{21}$$

Our first proposition states that the average productivity index is a strictly increasing function of the cutoff productivity level $\underline{\varepsilon}$.

Proposition 1 *The average productivity index, q, is a strictly increasing function of* $\underline{\varepsilon}$. *Moreover,* $\lim_{\underline{\varepsilon}\to 0} q(\underline{\varepsilon}) = \left(\int_0^\infty \varepsilon^\Delta f(\varepsilon)\mathrm{d}\varepsilon\right)^{1/\Delta} > 0$ *and* $\lim_{\underline{\varepsilon}\to\infty} q(\underline{\varepsilon}) = \infty$.

All proofs are given in the Appendix.

In a stationary equilibrium, the expected discounted profits of a new-entrant firm (before that firm's productivity is known) are $\Pi = (1/r_n)\int_{\underline{\varepsilon}}^\infty \pi_\varepsilon f(\varepsilon)\mathrm{d}\varepsilon$, where r_n is the discount factor of firms producing differentiated goods. Entry of firms is determined by the free-entry condition $\Pi = \lambda y$, whereby the expected discounted profits of a new entrant must be equal to its entry costs. We can use equations (18) and (20) to rewrite the free-entry condition as a function of the cutoff productivity level $\underline{\varepsilon}$. Thus, we have

$$(1 - F(\underline{\varepsilon}))\left[\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^\Delta + 1\right]\left[\left(\frac{\underline{\varepsilon}}{q}\right)^{-\Delta} - 1\right] = \frac{\lambda r_n}{\alpha(1-\theta)\phi}. \tag{22}$$

2.5 Closing the Model

The final good can be devoted to consumption c or to capital investment x_k, where the latter is used to produce differentiated goods. In equilibrium, the following equation must hold:

$$y = c + x_k. \tag{23}$$

In a stationary equilibrium, the ratio of investment to capital is constant and equal to

$$\frac{x_k}{k} = \delta_k, \tag{24}$$

where x_k is investment and δ_k is the depreciation rate of capital. We assume that there is a perfect rental market for capital and also that there are no capital adjustment costs. Hence the rental price of capital is

$$r_k = \rho + \delta_k, \tag{25}$$

where ρ is the interest rate. We assume that the closure of intermediate firms follows a homogeneous Poisson process and, therefore, the discount factor of intermediate firms is

$$r_n = \rho + \delta_n. \tag{26}$$

where δ_n is an exogenous rate reflecting each firm's risk of encountering, with probability δ_n, an adverse shock that leads to exit the industry.

A stationary equilibrium is characterized by equations (10)–(14) and (20)–(26). The following proposition establishes the existence of a unique stationary equilibrium.

Proposition 2 *A stationary equilibrium exists and is unique.*

Total factor productivity A is given by equation (14), which can be written, using (20), as a function of the cutoff productivity level $\underline{\varepsilon}$:

$$A = \Omega q^{1-\alpha}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta(1-\alpha)}\left[\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^\Delta + 1\right]^{\alpha\theta-1}; \tag{27}$$

here

$$\Omega \equiv \left(\frac{1}{\phi}\right)^{1-\alpha}\left[(1-\gamma)^{1-\gamma}\gamma^{\gamma}\right]^{1/(1-\gamma)}\left(\frac{1-\alpha}{\alpha(1-\theta)}\right)^{1-\alpha}. \tag{28}$$

Our next proposition establishes that TFP is a strictly increasing function of the cutoff productivity level.

Proposition 3 *Total factor productivity* A *is a strictly increasing function of the cutoff* $\underline{\varepsilon}$.

The following proposition establishes that, if entry costs increase, then the cutoff productivity level $\underline{\varepsilon}$ decreases, the average productivity index q decreases, and TFP A decreases.

Proposition 4 *The terms* $\underline{\varepsilon}$*, q, and* A *are strictly decreasing functions of* λ.

The ratio of stationary capital to output is given by $k/y = \alpha\theta/(r+\delta_k)$, which does not depend on entry costs, on the elasticity of substitution, or on the share of the intermediate input in gross output. Therefore, changes in these parameters will affect output only through changes in TFP.

2.6 Entry Costs, Complementarity and Aggregate Productivity

We will use the model to illustrate the mechanism through which the degree of complementarity between differentiated goods affects the negative impact of entry costs on average aggregate productivity. The free entry condition implies that an increase in λ must be offset in equilibrium by a decrease in the wage rate, w, so that the entry of firms remains profitable. To understand the role of complementarities in the wage adjustment, it is convenient to make explicit the relationship between the wage rate and the productivity cutoff in order to better understand why, for lower values of η, a higher fall in the productivity cutoff can be necessary to generate the same fall in the wage rate. From equations (11), (13), and (20), after a little algebra it follows that, in equilibrium, the wage rate equals the marginal productivity of labor of the firm with the cutoff productivity level

$$w = \alpha(1-\theta)\Omega^{1/(1-\alpha\theta)}\left(\frac{k}{y}\right)^{\alpha\theta/(1-\alpha\theta)}\left(\underline{\varepsilon}^{\Delta}q^{1-\Delta}\right)^{(1-\alpha)/(1-\alpha\theta)} \tag{29}$$

where Δ and Ω are given by (16) and (28), respectively. The marginal productivity of labor on the right-hand side of (29) depends on a weighted geometric average of the productivity level of the marginal firm (i.e., the cutoff) and the average aggregate productivity.

If differentiated goods are perfect substitutes, $\Delta = 1$, the marginal productivity of labor in the right-hand side of (29) only depends on the cutoff. However, when differentiated goods are less than perfect substitutes we have $\Delta<1$, and the marginal productivity of labor of the marginal firm that determines the wage rate depends less on the productivity cutoff and more on the average aggregate productivity, which itself is positively related to the cutoff. Therefore, a decrease in the cutoff needed to induce a fall in the wage rate has both direct and indirect effects on the marginal productivity determining the wage rate. Moreover, the higher is the complementarity, the lower is Δ, lowering the direct effect of a reduction in the cutoff and increasing the indirect effect through a reduction in the average aggregate productivity. This is the way complementarity affects the wage adjustment as a response to a change in entry costs.

To induce a decrease in the wage rate as a response to an increase in entry costs, do we need a bigger or a lower reduction in the cutoff when $\Delta<1$, compared to the change needed when $\Delta = 1$? The answer depends on which of those two forces dominates in the wage adjustment. If the decrease needed in the cutoff is bigger, then we will end up observing that higher entry costs will have a higher impact in reducing average aggregate productivity and TFP. The opposite will happen if the decrease needed in the productivity cutoff is smaller. The next section shows that, for a plausible numerical calibration of our model, a higher complementarity between differentiated goods generates a quantitatively bigger negative impact of entry costs on productivity.

3 EMPIRICAL RESULTS

3.1 Calibration

In order to test our model against the empirical evidence on the relationship between entry costs, TFP and GDP per worker, we give numerical values to the model's parameters as follows. The interest rate is set to $\rho = 0.041$ (as in McGrattan & Prescott, 2005), and the rate of depreciation is set to $\delta_k = 0.08$ (as in Klenow & Rodríguez-Clare, 2005). These values are standard in the literature. The parameter α captures the extent to which there are diminishing returns to scale in variable inputs at the firm level; it is set equal to 0.85. This value is also commonly used in the literature (see Atkeson & Kehoe, 2005; Restuccia & Rogerson, 2008) and is close to the value of 0.84 estimated by Basu (1996). We set $\alpha\theta = \frac{1}{3}$, the same value used by Klenow and Rodríguez-Clare (2005). Since $\alpha = 0.85$, it follows that θ is equal to 0.392. Djankov, Ganser, McLiesh, Ramalho, and Shleifer (2010) report an entry rate for the USA of 8.2% and, given that in the model's stationary state entry and exit rates are equal, we set $\delta_n = 0.082$.[9]

To set γ, we use the evidence provided by Jones (2011) where the share of intermediate inputs in US gross output is reported to be 46%, implying $\gamma = 0.46$. The parameter determining the elasticity of substitution, η, is assumed to be equal to 0.8. Using $\eta = 0.8$ is empirically reasonable given that this value is consistent with the estimates provided by Broda and Weinstein (2006) for the USA. However, given that these two parameters are the distinctive feature of our model, we will perform some sensitivity analysis by allowing them to take different values in order to check how sensitive the results are to the assumed numerical values.

With these parameter values, we follow Barseghyan and DiCecio (2011) and assume that ε is log-normally distributed with mean μ and standard deviation σ, and the mean, which is a scale parameter, is normalized to -10. We also use their strategy of using the model to calibrate σ and ϕ in order to replicate the distribution of employment and firm shares by size in the USA. To do this, notice that using equations (11) and (20) in equation (22), the latter can be written as

$$(1 - F(\underline{\varepsilon}))\left[\left(\frac{\underline{\varepsilon}}{q}\right)^{-\Delta} - 1\right] = \frac{\lambda y}{\phi w} r_n. \quad (30)$$

This equation makes clear that what matters for entry is the ratio of entry to overhead costs. Following Barseghyan and DiCecio (2011), we set this ratio to be 82%, implying that $\lambda y/\phi w = 0.82$ in equation (30).[10] Using equation (30) – instead of (22) – and $\lambda y/\phi w = 0.82$, we search for values of σ and ϕ that minimize the sum of squared errors of 18 moments in both the distribution of employment and firm shares by size in the USA, nine moments for each distribution. We use the model to compute the share of employment in firms with a number of employees within the following nine intervals: fewer than 5, 5–9, 10–19, 20–49, 50–99, 100–249, 250–499, 500–999 and more than 999. We also compute the share of firms within each employment interval. We end up with 18 moments generated by the model that can be compared with those computed from US data. Notice that the strategy of calibration removes the need to have a value for λ, since it only appears in equation (22) and, by writing this equation as in (30), we make the calibration depend on the ratio $\lambda y/w\phi$ which is observable and set equal to 0.82 for the US as noted above. However, since ϕ also affects the distribution of labor and firm share by size, we need a numerical value for ϕ in order to compute the moments generated by the model. Firstly, the employment level of the firm with the lowest productivity is endogenously determined in the model and, according to equations (12), (20), and (35), is given by

$$l_{\underline{\varepsilon}} = \frac{1-\alpha\theta}{1-\alpha}\phi,$$

where, in (35), we are using $q_0 \equiv \underline{\varepsilon}$. Secondly, the productivity levels associated to each of the eight employment levels l_j=5,10,20,50,100,250,500,999, mentioned above and giving rise to the nine employment intervals used for calibration, are given by

$$\varepsilon_j = \left(\frac{l_j-\phi}{\phi}\frac{1-\alpha}{\alpha(1-\theta)}\right)^{1/\Delta}\underline{\varepsilon}$$

where we are using (20) and (35), also with $q_j \equiv \varepsilon_j$.

In summary, we choose the values of ϕ and σ that bring the 18 model employment and firms distribution moments as close as possible to the data, using the sum of squared errors as the function to minimize. As a result we have ϕ = 0.49 for firm's operating costs and σ = 15.19 for the standard deviation of the log-normal distribution. Now, using (20) to compare equations (22) and (30), we can recover λ as

$$\lambda = 0.82\alpha(1-\theta)\phi\ \left(\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}+1\right)^{-1}, \tag{31}$$

which gives λ = 0.2115 for the entry costs.[11] The latter value can be understood as the sum of two terms: the regulatory component of that cost which, according to the World Bank's "Doing Business" report, was 0.0033 for the USA in year 2005, and what we call the non-regulatory component of the sunk entry cost which can be obtained as a residual from our calibration, resulting in 0.208. Table 1 displays the calibrated parameter values.

3.2 Complementarity, Intermediate Input Share and Total Factor Productivity: A Sensitivity Analysis

We noted earlier that the distinguishing feature of our model is the consideration of imperfect substitution between differentiated goods as well as the presence of intermediate inputs in the production of those differentiated goods. In terms of our model this implies that $\Delta \neq 1$. To check how relevant are both the complementarity between differentiated goods, η, and the share of

TABLE 1 Baseline Parameter Calibration

Borrowed from other sources					
Symbol	**Description**	**Value**	**Symbol**	**Description**	**Value**
ρ	Interest rate	0.041	θ	Elasticity of output to capital	0.392
δ_k	Depreciation rate	0.08	δ_n	Entry/exit rate	0.082
α	Decreasing returns to scale	0.85	η	Degree of differentiation	0.8
μ	Log-normal mean	−10*	γ	Share of intermediate inputs	0.46
Targeted					
Symbol	Description				Value
σ	Log-normal standard deviation				15.19
λ	Entry cost				0.212
ϕ	Overhead labor				0.49

* Scale parameter, normalized

intermediate inputs, γ, in delivering our results, we simulate the model's productivity for different values of λ while allowing η to be 1, 0.8 or 0.5 and[12] assigning to the remaining parameters the values given in Table 1. Then we repeat the exercise but with γ being either 0.38, 0.46 or 0.63 while[13] $\eta = 0.8$ and all the remaining parameters are again those in Table 1.

From our simulations there is one clear conclusion: changes in either the elasticity of substitution or the share of intermediate inputs considerably amplify the effects of entry costs on TFP, with the former having a considerably bigger effect than the latter. The simulations are shown in Figure 1. For ease of comparison it must be noted that the red line is the same both in the upper and lower panels of Figure 1, where also the axis scales are identical. If we adjust a linear regression to the results of the simulation, in the upper panel of Figure 1 a 1% variation in the entry costs delivers a change in TFP that ranges from −0.15% when $\eta = 1$ to −0.76% when $\eta = 0.5$. In

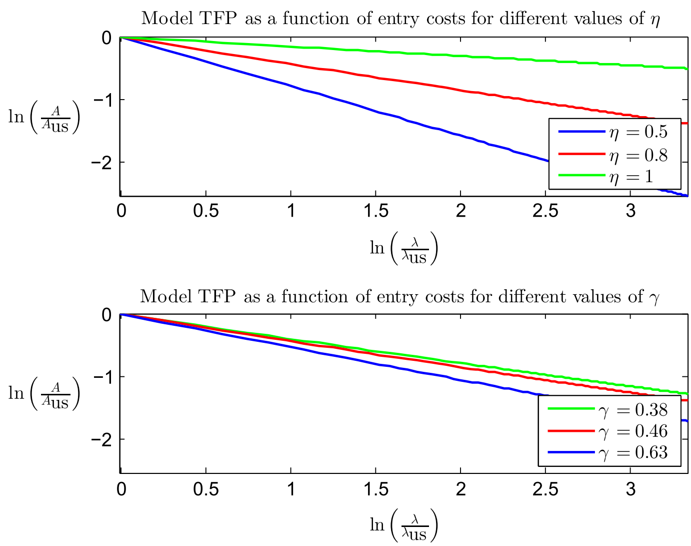

FIGURE 1 Model TFP as a Function of Entry Costs for Different Values of η and γ [Colour figure can be viewed at wileyonlinelibrary.com]

the lower panel of Figure 1 that sensitivity goes from −0.38% when $\gamma = .38$ to −0.50% when $\gamma = .63$.

The above exercises suggest that accounting for cross-country differences in the intermediate inputs share and, above all, in the elasticity of substitution of differentiated goods can help explain observed differences in productivity across countries. According to the results of our simulations, if two countries have the same entry costs then the country with the higher intermediate inputs share or lower elasticity of substitution has the lower productivity.

3.3 Entry Costs and Differences across Countries in TFP and GDP per Worker

Now we compare the model simulations with the data in order to test if the model can account for the observed relationship between entry cost and TFP and output per worker across countries, for reasonable values of complementarity between differentiated goods (i.e., for lower values of η) and of intermediate input share γ. We allow for η and γ to take the different numerical values used before and recalibrate σ and ϕ accordingly. Since the targeted parameters reported in Table 1 depend on the values of the parameters taken form other sources, every time we pick a different value for the latter we use the model to calibrate the former. Therefore, every time we change the numerical values of η and γ, we recalibrate the targeted parameters to consistently modify the scenario in which we perform cross-country comparisons. Tables 2 and 3 display the resulting targeted parameter values.

In order to identify reasonable cross–country values for λ, we use 2005 data on the legal fees required to open a business as reported by the World Bank for 99 countries. In the World Bank data, these legal fees are given as a percentage of per capita income. We multiply this percentage by the ratio of population to employment;[14] by doing this are able to write these entry fees as a fraction of output per worker. Then we add the value for the US ratio of entry costs to output per worker (calibrated using equation (31)), net of US legal fees, to each of these entry fees and so derive a value representing the overall entry costs for each country in our sample. We follow Barseghyan and DiCecio (2011) in assuming that the ratio of non-regulatory entry costs to output per worker is constant across countries. Data on GDP per worker and TFP are computed using 2005 data (for 99 countries) on capital stock, GDP, employment, and human capital; these data are taken from the PWT.[15]

Figure 2 plots the relationship between TFP and entry costs (both in logs and relative to the USA) in the model and in the data, for three different calibrations of the model corresponding to three different values of η. The slope of a linear relationship between TFP and entry costs in our model is −0.14, −0.42 and −1.17 when η is equal to 1, 0.8 (the baseline calibration), and 0.5, respectively. The slope of a linear relationship estimated from observed data is −0.89 when η is

TABLE 2 Calibration for Different Values of η*

Symbol	Description	$\eta = 0.5$ Value	$\eta = 1$ Value
σ	Log-normal standard deviation	36.75	3.72
λ	Entry cost	0.256	0.212
ϕ	Overhead labor	0.57	0.49

* The remaining parameters borrowed from other sources are those of Table 1.

TABLE 3 Calibration for Different Values of γ*

Symbol	Description	γ = .38 Value	γ = .63 Value
σ	Log-normal standard deviation	13.7	20.46
λ	Entry cost	0.212	0.212
ϕ	Overhead labor	0.49	0.49

*The remaining parameters borrowed from other sources are those of Table 1.

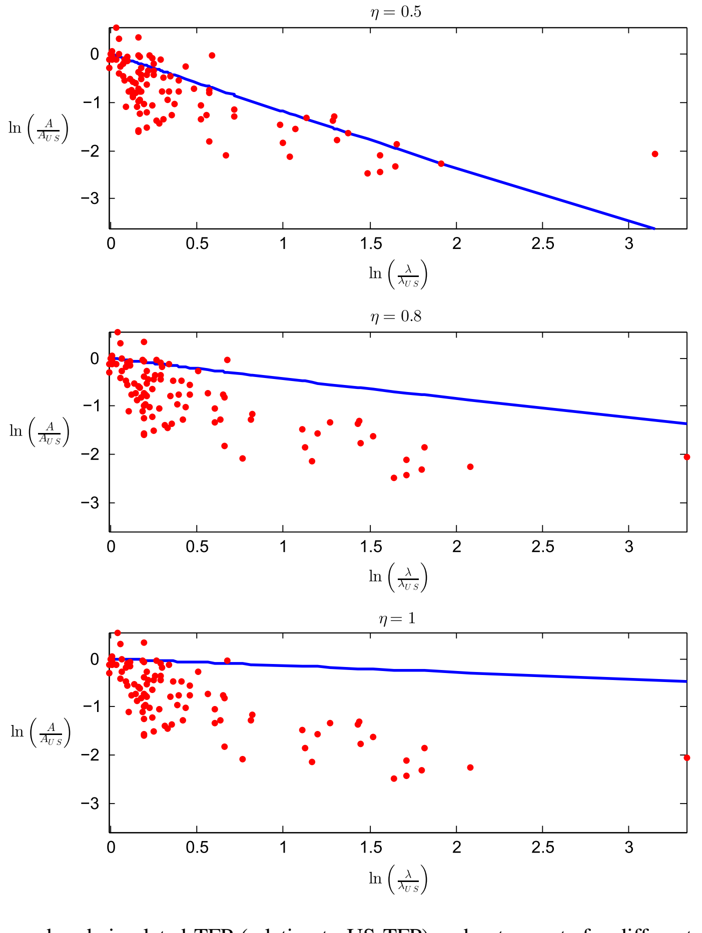

FIGURE 2 Observed and simulated TFP (relative to US TFP) and entry costs for different values of η [Colour figure can be viewed at wileyonlinelibrary.com]

either 1 or 0.8 and −0.96 when η = 0.5.[16] Therefore, the model accounts for 16%, 47% and 121% respectively of the average relationship (observed in the data) between entry costs and TFP.

Figure 3 shows the relationship between entry costs and GDP per worker. The slope of the linear relationship (observed in the data) between GDP per worker and entry costs is −1.60 when η = 1 or 0.8, and −1.71 when η = 0.5; in the model, that slope is −0.21, −0.63, and −1.76 for η equal to 1, 0.8, and 0.5, respectively.[17] So if η = 1 (η = 0.8, η = 0.5) then the model accounts for 13% (39%, 110%) of the average relationship (observed in the data) between entry costs and GDP per worker.

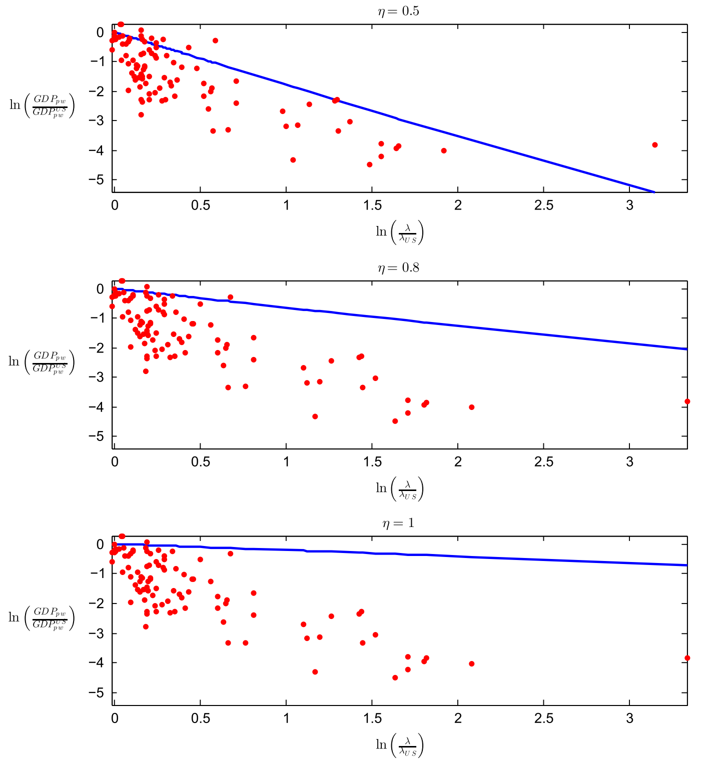

FIGURE 3 Observed and simulated GDP per worker (relative to US GDP) and entry costs for different values of η [Colour figure can be viewed at wileyonlinelibrary.com]

Concerning the different values of γ considered for simulation, the sensitivity of the results is much lower. The data giving rise to Figures 4 and 5, in which both empirical observations and simulations are displayed for two additional values of γ, show that the regression of the observed data on TFP and GDP is invariant to the value taken by γ, the reason being that the calibrated value of λ does not change with γ. They also show that the simulation results are much less sensitive to changes in γ than in η: the sensitivity of TFP to entry costs goes from -0.38 (when $\gamma = .38$) to -0.55 (when $\gamma = .63$), while the sensitivity of GDP per worker to entry costs is -0.57 and -0.82, respectively. As can easily be seen, changes in γ, compared to changes in η, have less influence on the effect of entry costs on productivity.

We also compare TFP differences between countries that exhibit the highest and lowest entry costs. In the model, if $\eta = 0.8$, then countries in the first decile (quartile) of the entry-cost distribution have, on average, 2.14 (1.64) times higher TFP than countries in the last decile (quartile). In the data, the corresponding values are 6.56 and 3.60, respectively. If $\eta = 1$ the model accounts for 20% (33%) of the observed difference in TFP between countries in the first and last deciles (quartiles); if $\eta = 0.8$, the model accounts for 33% (45%) of that observed difference; if $\eta = 0.5$ the model is able to account for 99% (86%) of the observed ratio between the first and tenth (fourth) TFP deciles (quartiles). See Table 4, where we also show that the influence of γ on the dispersion of TFP generated by entry costs is lower.

With an empirically plausible degree of complementarity between differentiated goods (e.g., $\eta = 0.8$), the model's performance improves considerably and is better able to reproduce the following empirical fact. In a thorough analysis involving the application of instrumental variables

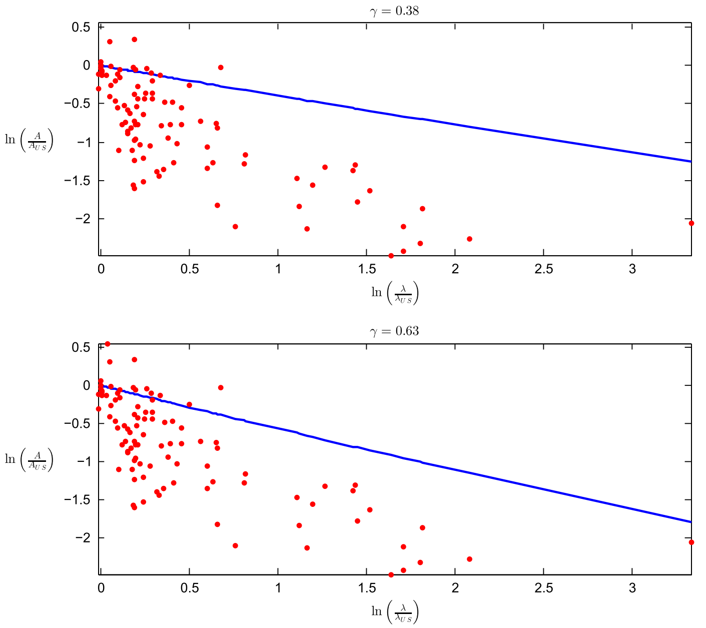

FIGURE 4 Observed and simulated TFP (relative to US TFP) and entry costs for different values of γ [Colour figure can be viewed at wileyonlinelibrary.com]

techniques to a data set of 97 countries, Barseghyan (2008) finds that increasing entry costs by 80% of per capita income (half a standard deviation in his sample) reduces TFP by 22% and GDP per worker by 29%. If $\eta = 0.8$ then our model implies that increasing entry costs by 80% of output per worker reduces TFP by 34% and GDP per worker by 50%; if $\eta = 1$ then our model is the

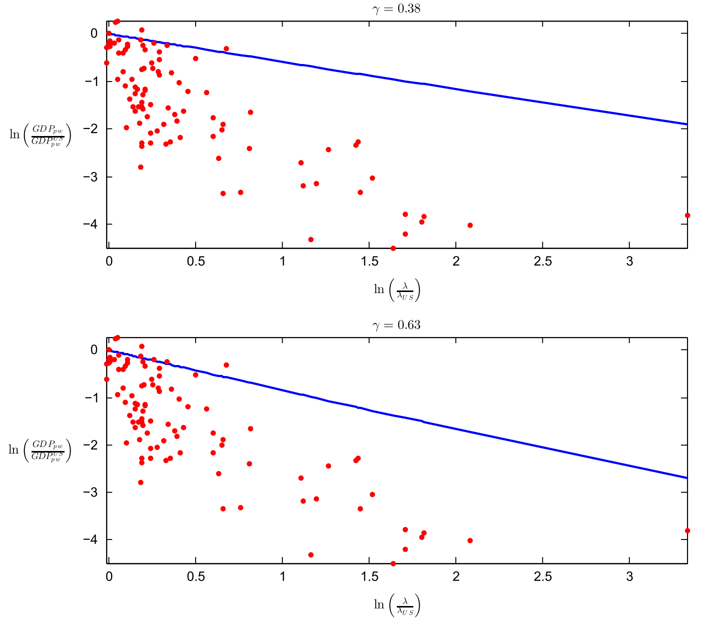

FIGURE 5 Observed and simulated GDP per worker (relative to US GDP) and entry costs for different values of γ [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Cross-country TFP Differences

		Simulations*				
	Data	$\eta = 0.5$	$\eta = 0.8$	$\eta = 1$	$\gamma = 0.38$	$\gamma = 0.63$
Average 1st decile TFP/average 10th decile TFP	6.56	6.53	2.14	1.29	2.01	2.70
Average 1st quartile TFP/average 4th quartile TFP	3.60	3.13	1.64	1.16	1.57	1.89

*For simulations, in each column all parameters except that in the column head are taken from Table 1.

same as in Barseghyan and DiCecio (2011) and, like them, it implies that the same increase in entry costs reduces TFP and GDP per worker by only 11% and 17%, respectively.[18] A value of η of about 0.9 allows us to obtain the Barseghyan (2008) estimates.

Finally, it must be emphasized that, in terms of the function we try to minimize in the calibration (the sum of squared errors of the 18 moments mentioned above), the parameters from Table 1 allow that function to achieve exactly the same minimum value as when the parameters of the second column of Table 2 are used, namely 9.27. However, with the parameters of the first column of Table 2 that minimum is equal to 1704.6, which means that the ability of the model to replicate the employment and firms distribution by firms size with the parameter values of Table 1 is the same as under the alternative listed in the second column of Table 2 and much better than when values from the first column of Table 2 are used. This is a reinforcing argument in favor of assuming an elasticity of substitution between differentiated goods lower than perfect but not too low, and of considering Table 1 parameter values as a reasonable scenario.

4 CONCLUSIONS

We develop a model in which higher entry costs allow lower-productivity firms to operate, which reduces firms' average productivity as well as aggregate TFP. In this framework, we introduce intermediate inputs as well as differentiated goods that are imperfect substitutes in production, in order to analyze the role played by links and complementarities across firms in amplifying the quantitative effects of entry costs on TFP and on GDP per worker. In short, we explore how links and complementarities across firms deteriorate resource misallocation caused by entry costs and amplify their effects on aggregate productivity.

We show that the negative effect of entry costs on aggregate productivity is significantly amplified by either a decrease in the elasticity of substitution between differentiated goods or an increase in the share of intermediate inputs in gross output, although the effect of the former is considerably larger. Therefore, our model identifies a plausible mechanism whereby a lower elasticity of substitution is able to increase the effect that misallocated resources have on aggregate productivity.

Our analysis reveals that introducing differentiated goods that are *not* perfect substitutes in production (and thus accounting for links and complementarities between firms, as suggested by Jones, 2011) enables the model to reproduce accurately the cross-country empirical evidence reported by Barseghyan (2008) concerning the negative effect of entry costs on TFP and on GDP per worker. Hence our analysis confirms that considering links and complementarities between firms can help to account for the effect, on TFP and also on output per worker, of distorted resource allocation. Such an accounting should contribute to our understanding of what causes the large disparities in income across countries.

END NOTES

1 See World Bank (2012). The World Bank's "Doing Business" reports are available online. Reported measures of entry costs were originally constructed by Djankov, La Porta, Lopez-de-Salines, and Shleifer (2002) and later expanded by the World Bank.

2 Jones (2011) uses data from the 2006 edition of the OECD Input–Output Database (see Yamano & Ahmad, 2006), which includes 35 countries and 48 industries.

3 Donovan (2014) reports that the intermediate inputs share in agriculture, but not in other sectors, is positively correlated with per capita GDP.

4 Using trade data at the four-digit level of aggregation for the USA in the period 1990–2001, Broda and Weinstein (2006) estimate that the elasticity of substitution between differentiated goods is on average 4.7, while the median of their estimates is 2.1. At the same level of aggregation the average of their estimates is 4.9 for reference priced goods and 11.6 for commodities, while the medians are, respectively, 2.9 and 3.5.

5 Moscoso-Boedo and Mukoyama (2012) also evaluate the effects of firing costs on cross-country productivity differences.

6 Ebell and Haefke (2009) and Felbermayr and Prat (2007) analyze the effect of entry costs on the unemployment rate.

7 This CES aggregator was proposed by Dixit and Stiglitz (1977) and then used extensively in the literature (e.g., Ethier 1982; Benassy 1996, 1998). Jones (2011) also uses a CES aggregator.

8 We assume that entry costs are proportional to output per worker, which is consistent with the empirical evidence reported by Bollard, Klenow, and Li (2016).

9 Dunne, Rogers, and Samuelson (1988), using data of US manufacturing industries from 1963 to 1982, found an average annual entry rate of about 8% and an average annual exit rate of about 7.5%.

10 Entry costs include regulatory and non-regulatory entry costs. World Bank (2011) provides information on the former, and the scarce evidence on the latter suggests that they mostly consist of capital purchases but also of market research and advertising; see Barseghyan and DiCecio (2011) and the references cited therein. To overcome the reduced evidence on both fixed and overhead costs, the literature resorts to estimates. The value of 0.82 used in our calibration is the average ratio of the estimates provided by Aguirregabiría and Mira (2007) for several Chilean industries (restaurants, gas stations, bookstores, shoe shops, and fish shops) and by Dunne, Klimkek, Roberts, and Xu (2009) for two US industries (dentists and chiropractors) in three different market settings.

11 We get the same values for ϕ and λ as in as Barseghian and DiCecio (2011) when $\eta = 1$, showing that, although in general employment and firms distributions do depend on ϕ, changing the value of η to 0.8 does not affect the calibrated values of ϕ and λ. Later on we will see that, if we consider other different values for η, the calibrated values of ϕ and λ can be different (see also Table 2).

12 As noted in the Introduction, Broda and Wenstein (2006) find compelling evidence in favor of an estimated average value of $\eta = 0.8$ for the USA, which implies an elasticity of substitution of 5. $\eta = 1$ (infinite elasticity of substitution) is the value used in the literature with which we want to compare. We also use $\eta = 0.5$, corresponding to an elasticity of substitution of 2, the median value estimated by Broda and Wenstein (2006) for the USA.

13 While $\gamma = .46$ is the US share of intermediate inputs in gross output reported by Jones (2011) and mentioned in the Introduction, .38 and .63 are the lowest and highest values of γ also reported by Jones (2011), corresponding respectively to Greece and China.

14 Data on employment and population are taken from Penn World Table (PWT) version 8.0; see Feenstra, Inklaar, and Timmer (2013).

15 Our data differ from that of Barseghyan and DiCecio (2011) on two counts. First, we use 2005 data whereas they use 2000 data. Second, our TFP figures are based on capital stock data taken from the PWT. These PWT data are, in turn, based on several different asset types (for an explanation, see Feenstra *et al.* 2013) and also on the assumption that the rate of depreciation is not the same in all countries (given that the composition of capital differs across countries).

16 Notice that the regression computed with data depends on the value of η we are using for calibration. The reason is that λ (the regressor) is the sum of non-regulatory and regulatory entry fees. The latter are taken from data and are different across countries; the former are calibrated and assumed to be equal across countries. Therefore, as

long as the calibrated value of λ changes (which happens for η = 0.5 but not for η = 1 or 0.8), the coefficient of the regression will be different.

17 As mentioned previously, in this model the capital–output ratio does not depend on entry costs. Therefore, the model-implied slope of the linear relationship between (the log of) GDP per worker and (the log of) entry costs is equal to the slope of the linear relationship between (the log of) TFP and (the log of) entry costs multiplied by $1/(1-\alpha\theta)$.

18 If η = 0.5, a 80% increase in entry costs reduces TFP and GDP per worker by 93% and 117%, respectively.

REFERENCES

Aguirregabiría, V., & Mira, P. (2007). Sequential estimation of dynamic discrete games. *Econometrica*, *75*, (1), 1–53.

Atkeson, A. & Kehoe, P. J. (2005). Modeling and measuring organizational capital. *Journal of Political Economy*, *113*, (5), 1026–1053.

Barseghyan, L. (2008). Entry costs and cross-country differences in productivity and output. *Journal of Economic Growth*, *13*, 145–167.

Barseghyan, L., & DiCecio, R. (2011). Entry costs, industry structure, and cross-country income and TFP differences. *Journal of Economic Theory*, *146*, 1828–1851.

Basu, S. (1996). Procyclical productivity: Increasing returns or cyclical utilization? *Quarterly Journal of Economics, 111*, (3), 719–751.

Benassy, J. P. (1996). Taste for variety and optimum production patterns in monopolistic competition. *Economics Letters*, *52*, 41–47.

Benassy, J. P. (1998). Is there always too little research in endogenous growth with expanding product variety? *European Economic Review, 42,* 61–69.

Bollard, A., Klenow, P. J., & Li, H. (2016). *Entry costs rise with development*. Unpublished manuscript, Stanford University.

Broda, C., & Weinstein, D. (2006). Globalization and the gains from variety. *Quarterly Journal of Economics*, *121*, (2), 541–585.

Dixit, A. K., & Stiglitz, J E. (1977). Monopolisitic competitions and optimum product diversity. *American Economic Review*, *67*, (3), 297–308.

Djankov, S., Ganser, T., McLiesh, C., Ramalho, S., & Shleifer, A. (2010). The effect of corporate taxes on investment and entrepreneurship. *American Economic Journal: Macroeconomics*, *2*, (3), 31–64.

Djankov, S., La Porta, R., Lopez-de-Salines, F., & Shleifer, A. (2002). The regulation of entry. *Quarterly Journal of Economics*, *117*, (1), 1–37.

Donovan, K. (2014). *Agricultural risk, intermediate inputs, and cross-country productivity differences*. Unpublished manuscript, University of Notre Dame.

Dunne, T., Klimkek, S. D., Roberts, M. J., & Xu, Y. (2009). The dynamics of market structure and market size in two health services industries. In T. Dunne, J. Jensen, & M. J. Roberts (Eds.), *Producer dynamics: New evidence from micro data*. Chicago: University of Chicago Press.

Dunne T., Rogers, M. J., & Samuelson, L. (1988). Patterns of firm entry and exit in U.S. manufacturing industries. *RAND Journal of Economics*, *19*(4), 495–515.

Ebell, M., & Haefke, C. (2009). Product market deregulation and the U.S. employment miracle. *Review of Economic Dynamics*, *12*, (3), 479–504.

Ethier, W. J. (1982). National and international returns to scale in the modern theory of international trade. *American Economic Review*, *72*, (3), 389–405.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2013). The Next Generation of the Penn World Table. Available from http://www.ggdc.net/pwt.

Felbermayr, G., & Prat, J. (2007). Product market regulation, firm selection and unemployment. *Journal of the European Economic Association*, *9*, (2), 278–317.

Hirschman, A.O. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.

Hopenhayn, H. A. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica*, *60*, (5), 1127–1150.

Hopenhayn, H. A., & Rogerson, R. (1993). Job turnover and policy evaluation: A general equilibrium analysis. *Journal of Political Economy*, *101*, (5), 915–938.
Hsieh, C.-T., & Klenow, P.J. (2009). Misallocation and manufacturing TFP in China and India. *Quarterly Journal of Economics*, *124*, (4), 1403–1448.
Jones, C. I. (2011). Intermediate goods and weak links in the theory of economic development. *American Economic Journal: Macroeconomics*, *3*, 1–28.
Jones, C. I. (2013). Misallocation, input-output economics, and economic growth. In D. Acemoglu, M. Arellano, & E. Dekel (Eds.), *Advances in economics and econometrics. Tenth World Congress, Volume II: Applied economics*. Cambridge: Cambridge University Press.
Klenow, P. J., & Rodríguez-Clare, A. (2005). Externalities and growth. In P. Aghion & S. Durlauf (Eds.), *Handbook of Economic Growth*, vol. 1A, (pp. 817–861). Amsterdam: Elsevier Science.
Kremer, M. (1993). The O-ring theory of economic development. *Quarterly Journal of Economics*, *108*, (3), 551–575.
Leontief, W. (1936). Quantitative input and output relations in the economic system of the United States. *Review of Economics and Statistics*, *18*, (3), 105–125.
Loayza, N., Oviedo, A. M., & Servén, L. (2005). *Regulation and macroeconomic performance* (World Bank Policy Research Working Paper No. 3469). World Bank, Washington, DC.
Marimon, R., & Quadrini, V. (2006). *Competition, innovation and growth with limited commitment*. *NBER Working Paper* No. 12474. National Bureau of Economic Research, Cambridge, MA.
McGrattan, E. R., & Prescott, E.C. (2005). Taxes, regulations, and the value of U.S. and U.K. corporations. *Review of Economic Studies*, *72*, (3), 767–796.
Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, *71*, (6), 1695–1725.
Moscoso-Boedo, H. J., & Mukoyama, T. (2012). Evaluating the effects of entry regulations and firing costs on international income differences. *Journal of Economic Growth*, *17*, 143–170.
Nicoletti, G., & Scarpetta, S. (2003). *Regulation, productivity, and growth: OECD evidence*. World Bank Policy Research Working Paper No. 2944. World Bank, Washington, DC.
Poschke, M. (2010). The regulation of entry and aggregate productivity. *Economic Journal*, *120*, (549), 1175–1200.
Restuccia, D., & Rogerson, R. (2008). Policy distortions and aggregate productivity with heterogeneous establishments. *Review of Economic Dynamics*, *11*, (4), 707–720.
World Bank (2012). *Doing Business 2012: Smarter Regulations for Small and Medium-Size Enterprises*. Washington, DC: International Bank for Reconstruction and Development/The World Bank.
Yamano, N., & Ahmad, N. (2006). *The OECD input-output database: 2006 edition*. OECD STI Working Paper No. 2006/8.

APPENDIX

Aggregation

From the first-order condition of the final firm (2), it follows that

$$\frac{p_i x_i}{p_j x_j} = \left(\frac{x_i}{x_j}\right)^{\eta} \tag{32}$$

for all $i,j \in [0,n]$.

From the first-order conditions of firms producing differentiated goods (equations (6)–(8)) we have

$$\frac{p_i x_i}{p_j x_j} = \frac{z_i}{z_j} = \frac{k_i}{k_j} = \frac{l_i}{l_j} \tag{33}$$

for all $i,j \in [0,n]$. By (33), (2) and (4),

$$\left(\frac{x_i}{x_j}\right)^{\eta} = \left(\frac{q_i}{q_j}\right)^{\Delta} \tag{34}$$

for all $i,j \in [0,n]$, where $\Delta=(1-\alpha)(1-\gamma)\eta/(1-\eta+(1-\alpha)(1-\gamma)\eta)$.

From the definitions of k, l, and z along with equations (32)–(34), it follows that

$$\frac{z}{z_j} = \frac{k}{k_j} = \frac{l}{l_j} = \left(\frac{q}{q_j}\right)^{\Delta} n; \tag{35}$$

here q is an average productivity index, which is given by

$$q = \left(\frac{1}{n}\int_0^n q_i^{\Delta} \mathrm{d}i\right)^{1/\Delta}.$$

From (4) and (35) we obtain

$$x_i = q_i^{\Delta/\eta}(q^{\Delta}n)^{-(\alpha(1-\gamma)+\gamma)}(k^{\theta}l^{1-\theta})^{\alpha(1-\gamma)}z^{\gamma}.$$

Taking into account equations (9) and (12), substituting the previous expression into equation (1) yields

$$y = Ak^{\alpha\theta},$$

where

$$A = \left(\frac{1}{\phi}\right)^{1-\alpha}[(1-\gamma)^{1-\gamma}\gamma^{\gamma}]^{1/(1-\gamma)}q^{1-\alpha}(1-l)^{1-\alpha}l^{\alpha(1-\theta)}.$$

From equations (3) and (9), together with (32)–(34), it follows that firm i's value added is

$$(1-\gamma)p_i x_i = \frac{y}{n}\left(\frac{q_i}{q}\right)^{\Delta}.$$

Proof of Proposition 1

From the definition of $q(\underline{\varepsilon})$, which is given by equation (21), we have on the one hand that

$$\lim_{\underline{\varepsilon}\to 0} q(\underline{\varepsilon}) = \left(\int_0^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon\right)^{1/\Delta} > 0$$

because $\lim_{\underline{\varepsilon}\to 0}(1-F(\underline{\varepsilon})) = 1$ and $\lim_{\underline{\varepsilon}\to 0}\int_{\underline{\varepsilon}}^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon = \int_0^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon$. On the other hand, $\lim_{\underline{\varepsilon}\to\infty}(1-F(\underline{\varepsilon})) = 0$ and $\lim_{\underline{\varepsilon}\to\infty}\int_{\underline{\varepsilon}}^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon = 0$. So applying l'Hôpital's rule yields

$$\lim_{\underline{\varepsilon}\to\infty} q(\underline{\varepsilon}) = \lim_{\underline{\varepsilon}\to\infty} \frac{-\underline{\varepsilon}^{\Delta} f(\underline{\varepsilon})}{-f(\underline{\varepsilon})} = \infty.$$

Differentiating equation (21), we obtain

$$q'(\underline{\varepsilon}) = \frac{1}{\Delta}\frac{q(\underline{\varepsilon})^{1-\Delta}}{(1-F(\underline{\varepsilon}))^2}\left[-(1-F(\underline{\varepsilon}))\underline{\varepsilon}^{\Delta} f(\underline{\varepsilon}) + f(\underline{\varepsilon})\int_{\underline{\varepsilon}}^{\infty} \varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon\right],$$

and, after a bit of algebra,

$$q'(\underline{\varepsilon}) = \frac{1}{\Delta}\frac{q(\underline{\varepsilon})^{1-\Delta} f(\underline{\varepsilon})\underline{\varepsilon}^{\Delta}}{(1-F(\underline{\varepsilon}))^2}\left[\int_{\underline{\varepsilon}}^{\infty}\left(\frac{\varepsilon}{\underline{\varepsilon}}\right)^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon - (1-F(\underline{\varepsilon}))\right];$$

this expression is strictly positive for all $\underline{\varepsilon}>0$ because

$$\int_{\underline{\varepsilon}}^{\infty}\left(\frac{\varepsilon}{\underline{\varepsilon}}\right)^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon > (1-F(\underline{\varepsilon})).$$

Proof of Proposition 2.

In order to prove Proposition 2, we first establish two useful lemmas as follows.

Lemma 1 H($\underline{\varepsilon}$) *as given by (22) is a strictly decreasing function of* $\underline{\varepsilon}$.

Proof: Equation (22) can be written as

$$H(\underline{\varepsilon}) \equiv (1-F(\underline{\varepsilon}))\left[\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+1\right][h(\underline{\varepsilon})-1] = \frac{\lambda R}{\alpha(1-\theta)\phi}, \tag{36}$$

where

$$0 < h(\underline{\varepsilon}) \equiv \left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta} = \frac{(1-F(\underline{\varepsilon}))\underline{\varepsilon}^{\Delta}}{\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon} < 1; \tag{37}$$

the reason being that

$$\int_{\underline{\varepsilon}}^{\infty}\left(\frac{\varepsilon}{\underline{\varepsilon}}\right)^{\Delta} f(\varepsilon)\mathrm{d}\varepsilon > 1-F(\underline{\varepsilon}).$$

We now differentiate the left-hand side of (36):

$$\begin{aligned} H'(\underline{\varepsilon}) = &-\frac{f(\underline{\varepsilon})}{1-F(\underline{\varepsilon})}H(\underline{\varepsilon}) \\ &+ (1-F(\underline{\varepsilon}))\left[\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{1}{h(\underline{\varepsilon})}-1\right) - \left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+1\right)\frac{1}{[h(\underline{\varepsilon})]^2}\right]h'(\underline{\varepsilon}); \end{aligned}$$

then, after a little algebra, we obtain

$$H'(\underline{\varepsilon}) = -\frac{f(\underline{\varepsilon})}{1-F(\underline{\varepsilon})}H(\underline{\varepsilon}) - \frac{1-F(\underline{\varepsilon})}{h(\underline{\varepsilon})}\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon}) + \frac{1}{h(\underline{\varepsilon})}\right)h'(\underline{\varepsilon}). \tag{38}$$

Differentiating (37) yields

$$
\begin{aligned}
h'(\underline{\varepsilon}) =& \frac{\underline{\varepsilon}^{\Delta}}{\left(\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon\right)^2}\left\{\left[-f(\underline{\varepsilon})+\Delta\underline{\varepsilon}^{-1}(1-F(\underline{\varepsilon}))\right]\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon+(1-F(\underline{\varepsilon}))f(\underline{\varepsilon})\underline{\varepsilon}^{\Delta}\right\}\\
=& \frac{\underline{\varepsilon}^{\Delta}}{\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon}\left[-f(\underline{\varepsilon})+\Delta\underline{\varepsilon}^{-1}(1-F(\underline{\varepsilon}))+h(\underline{\varepsilon})f(\underline{\varepsilon})\right]\\
=& \frac{h(\underline{\varepsilon})}{\underline{\varepsilon}}\left[\Delta-\frac{f(\underline{\varepsilon})\underline{\varepsilon}}{1-F(\underline{\varepsilon})}(1-h(\underline{\varepsilon}))\right]. \qquad (39)
\end{aligned}
$$

Substituting (39) into (38), we have

$$
\begin{aligned}
H'(\underline{\varepsilon}) =& -\frac{f(\underline{\varepsilon})}{1-F(\underline{\varepsilon})}H(\underline{\varepsilon})\\
& -\frac{1-F(\underline{\varepsilon})}{\underline{\varepsilon}}\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)\left(\Delta-\frac{f(\underline{\varepsilon})\underline{\varepsilon}}{1-F(\underline{\varepsilon})}(1-h(\underline{\varepsilon}))\right)\\
=& -\frac{1-F(\underline{\varepsilon})}{\underline{\varepsilon}}\Delta\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)\\
& -f(\underline{\varepsilon})\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+1\right)\left(\frac{1}{h(\underline{\varepsilon})}-1\right)\\
& +f(\underline{\varepsilon})\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)(1-h(\underline{\varepsilon}))\\
=& -\frac{1-F(\underline{\varepsilon})}{\underline{\varepsilon}}\Delta\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)\\
& -f(\underline{\varepsilon})\left(\frac{1-\alpha}{\alpha(1-\theta)}-\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}-1\right)\\
& +f(\underline{\varepsilon})\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})-\frac{1-\alpha}{\alpha(1-\theta)}[h(\underline{\varepsilon})]^2+\frac{1}{h(\underline{\varepsilon})}-1\right)\\
=& -\frac{1-F(\underline{\varepsilon})}{\underline{\varepsilon}}\Delta\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)\\
& -f(\underline{\varepsilon})\frac{1-\alpha}{\alpha(1-\theta)}\left(1-2h(\underline{\varepsilon})+[h(\underline{\varepsilon})]^2\right)\\
=& -\frac{1-F(\underline{\varepsilon})}{\underline{\varepsilon}}\Delta\left(\frac{1-\alpha}{\alpha(1-\theta)}h(\underline{\varepsilon})+\frac{1}{h(\underline{\varepsilon})}\right)\\
& -f(\underline{\varepsilon})\frac{1-\alpha}{\alpha(1-\theta)}(1-h(\underline{\varepsilon}))^2;
\end{aligned}
$$

this expression is negative for all $\underline{\varepsilon}\geq 0$.

Lemma 2 $\lim_{\underline{\varepsilon}\to 0}H(\underline{\varepsilon}) = \infty$ *and* $\lim_{\underline{\varepsilon}\to\infty}H(\underline{\varepsilon}) = 0$.

Proof: We start with

$$\lim_{\underline{\varepsilon}\to 0} h(\underline{\varepsilon}) \equiv \lim_{\underline{\varepsilon}\to 0}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta} = \lim_{\underline{\varepsilon}\to\infty}\frac{(1-F(\underline{\varepsilon}))\underline{\varepsilon}^{\Delta}}{\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon} = \frac{0}{\int_{\underline{0}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon} = 0,$$

$$\lim_{\underline{\varepsilon}\to\infty} h(\underline{\varepsilon}) \equiv \lim_{\underline{\varepsilon}\to\infty}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta} = \lim_{\underline{\varepsilon}\to\infty}\frac{(1-F(\underline{\varepsilon}))\underline{\varepsilon}^{\Delta}}{\int_{\underline{\varepsilon}}^{\infty}\varepsilon^{\Delta}f(\varepsilon)\mathrm{d}\varepsilon}.$$

An application of l'Hôpital's rule now yields

$$\lim_{\underline{\varepsilon}\to\infty} h(\underline{\varepsilon}) = \lim_{\underline{\varepsilon}\to\infty}\frac{-f(\underline{\varepsilon})\underline{\varepsilon}^{\Delta}+(1-F(\underline{\varepsilon}))\Delta\underline{\varepsilon}^{\Delta-1}}{-f(\underline{\varepsilon})\underline{\varepsilon}^{\Delta}} = 1-\Delta\lim_{\underline{\varepsilon}\to\infty}\frac{(1-F(\underline{\varepsilon}))}{f(\underline{\varepsilon})\underline{\varepsilon}} = 1.$$

Lemmas 1 and 2, together with the theorem of intermediate value, establish the existence of a unique value for $\underline{\varepsilon}$ that solves the free-entry condition (36).

Given a value for $\underline{\varepsilon}$ that solves this condition, there is a unique solution to the system consisting of equations equations (10)–(14), (20), (21), and (23)–(26).

Proof of Proposition 3

Differentiating total factor productivity, as given by (27) and (28), with respect to $\underline{\varepsilon}$ we obtain

$$\begin{aligned}
\frac{\partial A}{\partial\underline{\varepsilon}}\frac{1}{A} =& (1-\Delta)(1-\alpha)\frac{\partial q}{\partial\underline{\varepsilon}}\frac{1}{q}+\Delta(1-\alpha)\frac{1}{\underline{\varepsilon}} \\
&-\Delta\frac{(1-\alpha)(1-\alpha\theta)}{\alpha(1-\theta)}\frac{\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta-1}}{\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}+1}\left(\frac{1}{q}-\frac{\underline{\varepsilon}}{q^2}\frac{\partial q}{\partial\underline{\varepsilon}}\right) \\
=& \left[(1-\Delta)+\Delta\frac{\frac{(1-\alpha\theta)}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}}{\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}+1}\right](1-\alpha)\frac{1}{q}\frac{\partial q}{\partial\underline{\varepsilon}} \\
&+\Delta(1-\alpha)\frac{1}{\underline{\varepsilon}}\left[1-\frac{\frac{1-\alpha\theta}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}}{\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}+1}\right] \\
=& \left[(1-\Delta)+\Delta\frac{\frac{(1-\alpha\theta)}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}}{\frac{1-\alpha}{\alpha(1-\theta)}\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}+1}\right](1-\alpha)\frac{1}{q}\frac{\partial q}{\partial\underline{\varepsilon}} \\
&+\Delta(1-\alpha)\frac{1}{\underline{\varepsilon}}\left[1-\alpha\left(\frac{\underline{\varepsilon}}{q}\right)^{\Delta}\right].
\end{aligned}$$

This expression is strictly positive for all $\underline{\varepsilon}\geq 0$ because $0<(\underline{\varepsilon}/q)^{\Delta}<1$ and $0<\alpha<1$.

Proof of Proposition 4

The free-entry condition is given by (36). Lemma 1 states that $H'(\underline{\varepsilon})<0$ for all $\underline{\varepsilon}>0$, and Lemma 2 states that $\lim_{\underline{\varepsilon}\to 0}H(\underline{\varepsilon})=\infty$ and $\lim_{\underline{\varepsilon}\to\infty}H(\underline{\varepsilon})=0$. The right-hand side of (36) is strictly increasing in λ. Hence it follows that $\underline{\varepsilon}$ is a strictly decreasing function of λ. Then, by Proposition 1, the average productivity index is a strictly decreasing function of λ. Finally, by Proposition 3, TFP is a strictly decreasing function of λ.