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The Whole is Greater than the Sum of Its Parts: Complementary Reforms to Address Microeconomic Distortions*

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Abstract

This paper links microeconomic rigidities and technological adoption to propose a partial explanation for the observed differences in income per capita across countries. The paper first presents a neoclassical general equilibrium model with heterogeneous production units. It assumes that developing countries do not generate frontier technologies but can adopt them by investing in new capital, which requires firm renewal. The model analyzes how this process can be hindered by barriers to the entry of new investment projects and the exit of obsolete ones. It finds that there are nonlinearities in the way entry and exit barriers operate: Barriers have increasing costs, and they reinforce each other's negative impact. The paper then calibrates and simulates the model to measure the impact of these barriers on the GDP per capita gap between the U.S. and a large sample of developing countries. It accounts for a range of 26 to 60% of the income gap between the U.S. and 107 developing countries. Most importantly, the model implies that, for the median developing economy, about 50% of the simulated gap is explained by the interaction of entry and exit barriers (and the rest by their individual effects). The paper's main policy implication is that only comprehensive reforms can have substantial effects, especially when initial distortions are large. If they are too narrow (focusing on only one barrier) or too mild (leaving in place a large distortion), microeconomic reforms are unlikely to have significant effects on aggregate productivity and output growth.

JEL: O1, O4
Keywords: firm dynamics, technological adoption, regulatory distortions, economic growth, development gap.

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1. Introduction

There is a large disparity among countries regarding the rate of technological adoption, and this is reflected in large differences in income levels.[1] To understand why, we focus on impediments to firm dynamics, especially regarding the entry and exit of production ventures. When firm renewal is unrestrained, companies are able to incorporate the advances of a rising technological frontier. In contrast, when firm renewal is obstructed (for instance, by regulatory or institutional barriers), an economy's ability to adopt new technologies can be severely handicapped, with negative consequences for long-run income.

In this paper, we argue that a sizable fraction of the gap in income per capita between the U.S. and developing countries is accounted for by barriers to firm renewal. Moreover, we argue that not just removing these distortions, but removing them jointly is critical: about half of the estimated gap between the U.S. and the median developing economy is explained by the interaction of different distortions, and the rest by the sum of their individual effects. This conclusion is robust to a wide range of parameter values and to different model specifications. From a policy perspective, we argue in favor of complementary reforms: In the face of multiple barriers, reforms that alleviate them jointly have a larger payoff than those that address them separately.

Starting with the work of Hopenhayn and Rogerson (1993), Caballero and Hammour (1994), and Davis, Haltiwanger, and Schuh (1996), and more recently Restuccia and Rogerson (2008) and Hsieh and Klenow (2009), a large body of literature shows the key role of firm dynamics in driving microeconomic productivity and, consequently, aggregate growth. Firm entry and exit, involving the reallocation of resources from less to more efficient economic units, explain a substantial share of productivity improvements in the economy (see, for example, for example Foster, Haltiwanger, and Krizan, 2001). Resource reallocation, however, implies costly adjustment: It requires the adoption of new technologies and assimilation of production inputs by expanding firms, and the shedding of labor and capital by declining firms. Without this costly process, economies would be unable to both reap the benefits of an expanding production

[1] See Comin, Hobijn and Rovito (2006) and Comin and Mestieri (2013). Using data from the last two centuries, Comin and Mestieri (2013) shows that varying patterns of technological diffusion account for 80% of the divergence between rich and poor countries since 1820.

possibilities frontier --the source of long-run growth - and absorb and accommodate negative shocks --the antidote to protracted recessions (see Bergoeing, Loayza, and Repetto, 2004).

Some of the impediments to firm renewal are related to the development status of the economy, such as poor governance and lack of human capital, which exacerbate the contractual, financial, and adaptation costs of new technologies (see Caballero and Hammour, 1998; and Acemoglu and Zilibotti, 2001). Other impediments result from government's distorting interventions in markets, such as excessive labor regulations, subsidies to inefficient sectors and firms, barriers to the establishment of new firms, and burdensome bankruptcy laws (see Parente and Prescott, 2000; Bernanke, 2005; and Loayza and Serven, 2010).[2]

In this paper, we analyze the process of technological innovation as the driver of economic growth from the perspective of developing countries. We assume that developing countries do not generate frontier technologies but can adopt available ones by investing in new capital.[3] In this context, technological adoption requires firm renewal. We analyze how this process can be hindered by impediments to the entry of new investment projects and the exit of obsolete ones.[4] Moreover, we analyze how these regulatory or institutional barriers interact with each other to affect firm dynamics and, consequently, technological adoption. As we explicitly model the connection between microeconomic distortions and technological adoption, we provide an explanation for endogenous productivity changes in developing countries.

To be more precise, we construct a neoclassical general equilibrium model with heterogeneous productive units, or plants for short. Plants differ on their level of productivity. New plants acquire new capital and draw their productivity level from a distribution function

[2] Parente and Prescott (2000) argues that gaps in total factor productivity (TFP) among economies are produced by country-specific policies that restrict the set of technologies that individual production units can use. Bernanke (2005) points to heavy regulatory burden as the reason why Europe lags behind the U.S. regarding productivity growth. Likewise, Nicoletti and Scarpetta (2003) concludes that the presence of government-owned firms with a degree of monopoly power, together with restrictions on the entry of new firms, diminishes competitive pressures that foster innovation and greater efficiency in the OECD. Focusing also on developed countries, Gust and Marquez (2004) presents empirical evidence that countries with highly regulated labor and product markets face greater difficulty in incorporating information technologies and suffer from lower productivity growth. Loayza and Serven (2010) focuses on developing countries, assessing the impact of excessive business regulations on firm dynamics, labor and production informality, and aggregate growth and volatility.

[3] Most papers on entry and exit frictions usually do not consider advancing technologies. Two exceptions are Luttmer (2007) and Poschke (2009), which however focus on the determination of the frontier growth rate, and analyze somewhat different frictions.

[4] Acemoglu et al. (2006) and Jovanovic (2009) provide alternative explanations for the lack of technological innovation among developing countries.

whose mean grows exogenously over time, representing technological progress in the rest of the world. Old (or incumbent) firms draw their productivity level from a random walk process without drift, thus becoming relatively less and less productive and eventually leaving the market. In so doing, they release resources that may be used to create new firms, with capital that embodies the leading edge technology. This process of firm renewal is hampered by frictions in the entry and exit margins, with negative consequences for technological adoption and, therefore, long-run growth and income levels. Since these frictions vary widely across countries, the model can generate large income disparities between countries, disparities which accumulate and grow as the world technology frontier expands.

We calibrate the model economy to the U.S. and 107 developing countries. Proxies for entry and exit barriers are taken from the World Bank *Doing Business* database. Two specific indicators are of interest: the cost of starting a business (entry) and the cost of bankruptcy (exit). Additionally, we consider an alternative setup where exit barriers are calibrated to match the costs of firing labor. We then conduct simulation exercises to analyze the impact of entry and exit barriers, as well as the effect of their mutual interaction. The model accounts for a range of 26 to 60% of the income gap between the U.S. and developing countries in the sample. Moreover, the model implies that 20 to 56% of this gap is explained by the interaction of entry and exit barriers, with the rest explained by the sum of their individual effects.

We emphasize that these estimates should be considered with caution, especially those related to the simulated output gap. First, the *Doing Business* database may be subject to measurement error and imperfect cross-country comparability, as most other international databases are. Second, the mapping between the data's cost of starting a business and cost of bankruptcy (or alternatively, firing costs) and the model's entry and exit barriers is not ideal. Unfortunately, there are no alternative databases or alternative indicators measuring consistently entry and exit barriers for such a large set of countries. We are, however, more confident in our estimates for the relevance of the interaction effect. We show that this complementarity is quantitatively relevant even for entry and exit barriers with values much smaller than those obtained from the *Doing Business* database.

Let's go back to the received literature and review the papers that most closely precede ours. The first paper to study the effects of distortions to the extensive margin of firm dynamics in general equilibrium is Hopenhayn and Rogerson (1993). It quantifies the impact of labor firing costs on consumption per capita and aggregate productivity, finding sizable effects.[5] The creation of the World Bank *Doing Business* database stirred work measuring the effect of entry or exit costs on aggregate productivity across countries. Most of it, such as Barseghyan (2008) and Barseghyan and DiCecio (2011), focuses on a single distortion. There are, however, some notable exceptions. Poschke (2010) studies entry barriers and rigid labor markets and finds that the reduction in productivity resulting from entry costs is larger when labor markets are not competitive. Moscoso and Mukoyama (2012) and D'Erasmo and Moscoso (2012) consider the interaction between entry and exit distortions. Similarly to ours, the first paper analyzes the combined effect of entry regulations and firing costs for a sample of countries using the *Doing Business* dataset. In contrast to ours, the paper finds small complementarity for developed countries and even substitutability for developing countries in lifting different distortions. The reason behind the different results lies in the way we model technological adoption: By requiring new technologies to be embodied in capital investment, we generate a direct link between firm entry and exit.[6] In our model, ease of entry makes the shedding of old (and less productive) projects more attractive, and ease of exit releases more resources than can then be used for new projects.[7]

Before we turn to the theoretical model, let's consider some motivating evidence on the importance of regulatory barriers for technological adoption. As mentioned above, differences across countries regarding technological adoption are quite large. Studying 115 technologies in

[5] Two important papers studying distortions and TFP gaps across countries are Restuccia and Rogerson (2008) and Hsieh and Klenow (2009). Restuccia and Rogerson (2008) shows that policy distortions faced by individual plants can lead to decreases in output and TFP in the range of 30 to 50%. Hsieh and Klenow (2009), using micro data on manufacturing establishments, calculates manufacturing TFP gains of 30-50% in China and 40-60% in India if labor and capital inputs are allocated as in the U.S. These papers have a different approach from ours, as they seek to *recover* the distribution of (plant-specific) distortions that are implied by given aggregate TFP differences.

[6] On the importance of embodied technological change, Samaniego (2007 and 2010) have recently extended Hopenhayn and Rogerson (1993) to allow for capital accumulation and investment specific technological change (ISTC). Using the Eurostats database, Samaniego (2010) finds a strong positive link between industry turnover and productivity growth in industry-specific capital goods. Further, it finds that high entry costs suppress not only entry but also exit in industries with high ISTC, providing empirical evidence in favor of complementary reforms. Moreover, Samaniego (2010) shows that its empirical findings are consistent with a general equilibrium model with embodied technological change.

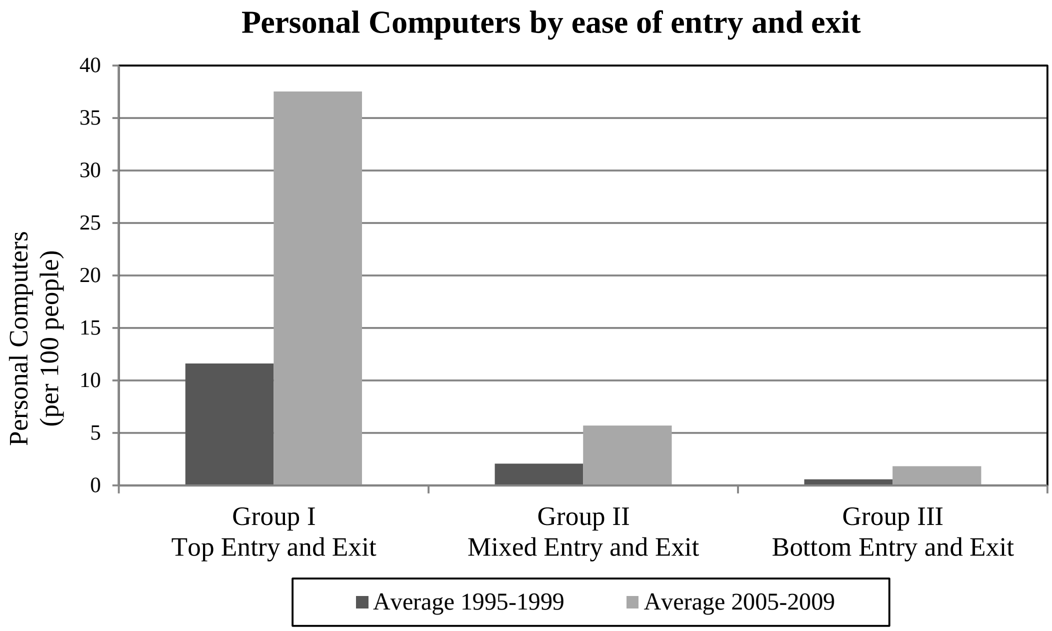
[7] D'Erasmo and Moscoso (2012) uses a similar approach to Moscoso and Mukoyama (2012), but instead of considering firing costs, it analyzes how financial frictions and entry costs affect the decision of moving from the informal to the formal sector (with a more efficient technology). This model also implies low complementarity from removing distortions jointly. Conversely, in a more recent application that allows for endogenous human capital, D'Erasmo, Moscoso, and Senkal (2011) does find sizeable complementarities from removing different distortions.

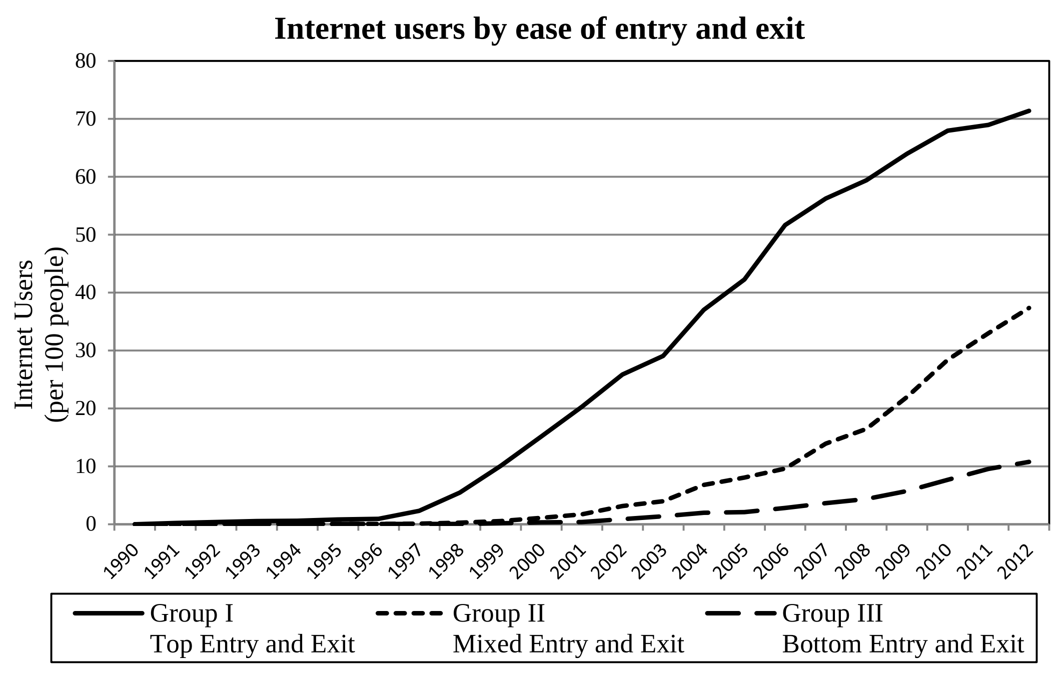
150 countries, Comin, Hobijn, and Rovito (2006) concludes that the average dispersion of technology across countries is 3 times larger than the dispersion of income per capita. What explains these technological gaps? Most technologies have quite long gestation and adaptation processes, which makes it hard to identify the causes underlying their cross-country variation. The technologies related to the information revolution, however, offer an interesting exception: less than three decades ago, they were practically nonexistent almost everywhere; since then, they have been adopted at different rates throughout the world.

To maximize data quality and coverage across countries, consider two indicators: The number of personal computers (per population) as proxy for technological progress in production and management processes; and the number of internet users (per population) as proxy for the advance in telecommunications and information gathering. Cross-country comparisons are revealing. By the second half of the 2000's, the typical OECD country had 7 times more personal computers per capita than the typical East Asian country, 6 times more than the typical Eastern European or Central Asian country, about 8 times more than the typical Latin American or Middle Eastern country, and about 70 times more than the typical Sub-Saharan African country. Though smaller, the gaps regarding internet usage are also substantial.

These differences are clearly related to income levels, providing some evidence on the importance of developmental barriers. What about regulatory barriers, particularly on firm entry and exit? Figure 1 suggests that they are also potentially important. Using the *Doing Business* database, we divide countries into three groups according to how they rank on ease of entry and exit: Group I comprises countries at the top half of both rankings, Group II includes countries at the top half of one of the rankings but not both, and Group III has countries at the bottom half of both rankings. For each of them, we plot the typical level of personal computers and internet users per population for various periods, up to the most recently available. Countries in Group I have much higher levels and speeds of adoption for both technology indicators. Countries in Group III lag far behind the others, and those in Group II are somewhere in the middle.

Figure 1. Technological innovation and ease of starting and exiting a business





Notes:

1. Chart 1 shows the median number of personal computers per one hundred people for each group of countries. Chart 2 similarly shows median number of internet users per group.
2. Groups are defined using 2005 rankings of countries for ease of starting a business (entry) and resolving insolvency (exit). Group I comprises the countries at the top of both rankings, i.e. entry and exit ranking above the median; Group II includes countries with only one rank above the median; and Group III, countries with both ranks below the median.
3. Data on Personal Computers and Internet Users are from the *World Development Indicators*. Data on ease of starting a business and resolving insolvency are from *Doing Business*.

For a bit more formal analysis, consider the cross-country regressions presented in Table 1. As dependent variables, we use the change between the second half of the 1990s and the second half of the 2000s in each personal computers and internet users (both normalized by population). As explanatory variables, we consider, first, the proxies for ease of entry and exit; second, an interaction between the two; and third, the initial level of GDP per capita and the average number of schooling years in the adult population (mainly as controls for developmental barriers). With caveats as to their interpretation, we simply use the *Doing Business* rankings for ease of entry and exit (with larger numbers meaning better standing).

Table 1. Technological innovation and the complementarity of Entry and Exit

Method of estimation: Ordinary Least Squares with Robust Standard Errors

	Change in Personal Computers (per 100 people)			**Change in Internet Users (per 100 people)**		
Ease of Entry (Starting a Business from the Doing Business Report; rank inverted)	0.99** [3.28]	-0.20** [-3.08]	-0.20** [-3.49]	0.12** [3.11]	-0.09 [-1.01]	-0.11 [-1.63]
Ease of Exit (Resolving Insolvency from the Doing Business Report; rank inverted)	0.14** [4.97]	-0.05 [-1.23]	-0.09** [-2.63]	0.26** [6.29]	0.12** [2.04]	0.02 [0.53]
Ease of Entry * Ease of Exit		0.003** [4.74]	0.002** [4.08]		0.002** [2.67]	0.001 ** [2.11]
Schooling (average schooling years in the population aged 15 and over, from barrolee.com)			1.56** [4.10]			3.50** [5.94]
GDP per capita, PPP (GDP per capita, PPP adjusted, in constant 2011 international dollars, from WDI)			0.0003** [2.73]			0.0005** [4.01]
Number of Observations	103	103	103	103	103	103
R-squared (adjusted)	0.40	0.49	0.63	0.47	0.48	0.73

Notes:

1. T-statistics are presented below the corresponding coefficients. * and ** denote significance at the 10 percent and 5 percent levels, respectively. Constant terms are included but not reported.
2. Variables on personal computers are measured as the change from the average of the period 1995-1999 to the average from 2005-2009. In the case of internet users, it is the change from the average of the period 1995-1999 to the average from 2005-2010. Ease of entry and exit variables are measured as of 2005 and schooling indicator and GDP per capita as of 1995.
3. Data on personal computers are from the *World Telecommunication/ICT Indicators Database*, on Internet users from the *World Development Indicators*, and on explanatory variables, as indicated below each variable.

When ease of entry and exit are included as the only explanatory variables, they both carry positive and significant coefficients, suggesting a beneficial impact on technological adoption. When, in addition, the multiplicative interaction between entry and exit is included, its presence dominates the linear terms, capturing a positive and significant coefficient. We interpret this result as suggestive of a strong complementarity between reforms that improve exit and entry. This effect is preserved, in sign and significance, when GDP per capita and schooling are added to the regression (with each of them carrying the expected positive and significant coefficient).[8]

The remainder of the paper is organized as follows. Sections 2 and 3 present the model and its calibration, respectively. Section 4 discusses the results, first exploring the economic mechanism and then using it to measure the GDP per capita gap between the U.S. and a large sample of developing countries. Section 5 concludes.

2. A model of technological adoption by firm renewal

We develop a general equilibrium model of heterogeneous production units, vintage capital, and idiosyncratic shocks, based on Hopenhayn (1992), Campbell (1998) and Bergoeing, Loayza and Repetto (2004). We consider a neoclassical growth model with endogenous entry, exit, and heterogeneity of production units. The economy consists of a continuum of identical and infinitely-lived consumers and a single firm that produces using a continuum of production units. At any given time there is a distribution of production units, or plants for short, characterized by different levels of productivity.

Incumbent plants carry a level of embodied technology corresponding to their vintage. Their individual productivity level follows a random walk and can be different across plants of the same vintage. In addition, plants can be created (entry) or scrapped and sold in units of the consumption good (exit). Before starting production but after entering the market, a new plant receives a technological shock that determines its initial productivity. The key difference between new and incumbent plants is that the former receive a productivity innovation with

[8] Note that the coefficients on ease of entry and ease of exit themselves become zero or negative once the interaction is included. Taken literally, this implies that ease of entry has a positive marginal effect only if ease of exit is large enough, and otherwise it has a negative effect. This may seem rather implausible. In additional exercises, where we include other non-linear terms, we find that the marginal effect of ease of entry (exit) is not significantly different from zero when ease of exit (exit) is low. Given that we use rankings as proxies for entry and exit ease, we prefer not to make too much of results under these more complex specifications. The important point to underscore is that the entry-exit interaction remains significantly positive.

expected value equal to what we call the *leading edge technology,* while the latter keep their productivity constant in expected value.

We assume that the leading edge technology grows exogenously, thus generating an incentive for the firm to scrap old, low-productivity plants and invest in new ones. However, exiting the market is costly as capital loses some of its value in the process. This investment irreversibility, as modeled in Caballero and Engel (1999), combined with idiosyncratic uncertainty, generates an equilibrium solution where plant exit is rationally delayed. Thus, the economy is characterized by an ongoing process of Schumpeterian creative destruction: incumbent plants exit if their current technology becomes obsolete and, by investing in new capital, entering firms gain access to the leading edge technology.

Note that in order to relate our model to the existing firm dynamics literature, we refer to production units as plants. In reality, a plant is a collection of production units, and therefore, the entry and exit dynamics represented in the model can occur either within or across actual plants. The gap between the definition of a plant in the model and in the data has implications for both the specification of parameters in the calibration and the interpretation of results. However, to the extent that a plant consists of interrelated production units we expect considerable correlation between production dynamics in the model and actual plant dynamics.

Finally, we consider the effect of exogenously imposed rigidities, that is, regulatory or institutional distortions that alter plants' decisions to leave or stay in the market. Governments may be inclined to impose such measures to reduce the economic volatility and the short-run social and political costs associated to the entry and exit process. Larger regulatory or institutional barriers will imply slower creative destruction processes at the plant level and lower rates of technological adoption for the overall economy.

2.1 The consumer and the market for production units

Time is discrete and indexed by $t=0,1,\ldots$ There is a continuum of identical infinitely-lived consumers and a representative firm. Consumers are endowed with one unit of time per period, which they allocate between work, n, and leisure, $1-n$. Consumers' utility depends on the streams of consumption and leisure according to

$$\sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \kappa(1-n_t)\right] \qquad (1)$$

where $\beta \in (0,1)$ and $\kappa > 0$ are, respectively, the subjective time discount factor and the marginal utility of leisure. Notice that we assume that the utility function is linear in leisure.[9] Following Hansen (1985) and Rogerson (1988), this can be interpreted as an environment in which consumers, with standard utility functions, work either a fixed number of hours or none at all, trading employment lotteries. Thus, n_t can be interpreted as the fraction of the population that works at time *t*.

In turn, each period is divided into three sub-periods, which for simplicity we call morning, day, and evening. At the beginning of the period there is a continuum of heterogeneous plants indexed by their embodied technology $\theta \in (-\infty, \infty)$. In the morning, the measure of each type of plant is $k_t^0(\theta)$, and they are all owned by consumers. There is a morning market for plants and labor, where consumers sell their portfolio of plants to the firm at price $q_t^0(\theta)$ per unit and rent their endowment of time at wage rate ω per unit. Labor and production take place during the day. In the evening, markets open again: consumers use their labor income and the proceeds from their portfolio of plants to consume, to buy back the plants from the firm, in quantity $k_t^1(\theta)$ at price $q_t^1(\theta)$ per unit, and to invest in new plants I_t. The task of constructing new plants is delegated to an intermediary, who charges a gross rate of q_t^c per unit of capital constructed.[10] Thus, the consumer's budget constraint is,

$$c_t + I_t q_t^c + \int_{-\infty}^{\infty} q_t^1(\theta) k_t^1(\theta) d\theta = \omega_t n_t + \int_{-\infty}^{\infty} q_t^0(\theta) k_t^0(\theta) d\theta + T_t. \qquad (2)$$

The first term on the right hand-side of equation (2) is total labor income, the second term represents proceeds from the sale of the plants in the morning market, and the third term is a lump-sum transfer from the government. The sole purpose of the lump-sum transfer is to balance the government's budget constraint period by period. The left hand-side of equation (2) encompasses how the consumer uses her income. The first term represents consumption expenditures (with price equal to 1), the second term is investment in new plants, and the third term is the total amount spent on incumbent plants in the evening market.

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[9] If we run the numerical simulations using a log utility function for leisure, the main results remain qualitatively unchanged.

[10] The division of the calendar time into sub periods is an innocuous assumption that allows us to price the firms in each period and at any time information changes. In this sense, the prices of units of capital, both at the beginning and at the end of the period, are equivalent to the value functions of each plant at the beginning and at the end of the period, respectively. This approach greatly simplifies the numerical solution of the economy.

2.2 The technology: stochastic processes

Between periods both new and incumbent plants receive random shocks to their embodied technology. However, the two kinds of plants draw their shocks from different distributions. Newly constructed plants have embodied the leading edge technology z_t, and they receive a shock normally distributed around this value. That is, the initial productivity level of a plant born in period *t* is a random variable with Normal distribution $\theta_{t+1} \sim N(z_t, \sigma_z^2)$, where z_t and σ_z^2 are the mean and variance, respectively. The leading edge technology, z_t, grows at a positive and exogenous rate.[11]

Previously existing plants receive idiosyncratic shocks that are normally distributed around their current level of productivity. That is, the productivity of incumbent plants follows a random walk without drift, $\theta_{t+1} = \theta_t + \varepsilon_{t+1}^{\theta}$, where $\varepsilon_{t+1} \sim N(0, \sigma_\theta^2)$. This idiosyncratic shock has zero mean and, therefore, does not affect the economy's growth rate. The random walk property of the stochastic process ensures that the differences in average productivity across production units persist over time. That way, at any *t*, the plants with more advanced technology have a lower probability of shutting down.

Then, we can interpret the decision for plants to stay in or leave the market as choosing between the following distributions:

$$\theta_{t+1} \sim N(\theta_t, \sigma_\theta^2) \qquad (3)$$

$$\theta_{t+1} \sim N(z_t, \sigma_z^2), \qquad (4)$$

Given these stochastic processes and the measure of plants at the end of each period, $k_t^1(\theta)$, the measure of plants at the beginning of next period, $k_{t+1}^0(\theta)$, is given by,

$$k_{t+1}^0(\theta_{t+1}) = \int_{-\infty}^{\infty} \frac{1}{\sigma_\theta} \phi\left(\frac{\theta_{t+1} - \theta_t}{\sigma_\theta}\right) k_t^1(\theta) d\theta + \frac{1}{\sigma_z} \phi\left(\frac{\theta_{t+1} - z_t}{\sigma_z}\right) I_t, \text{ for all } \theta_{t+1} \qquad (5)$$

[11] To be precise, as shown later, the plant's productivity is measured as e^{θ}, rather than θ. For ease of exposition, we refer to θ as the plant's productivity. Given the assumption on the Normal distribution of θ, it is immediate that the plant's productivity measured as e^{θ} has a Lognormal distribution.

where $\phi(.)$ is the density of the Normal distribution. The first term of the right-hand side of equation (5) is the measure of incumbent plants (that is, the plants that have not been scrapped), and the second term is the measure of new plants.

2.3 The firm and production

The economy has a single firm. The firm chooses how many plants to buy in the morning market, how much labor to allocate to each plant for production during the day, which plants to sell in the evening market, and which plants to scrap. All plants produce the same good, which can be used for consumption or investment. This production good is the numeraire.

Each plant's production function is given by

$$y_t = An_t^{\alpha}\left(e^{\theta_t}k_t\right)^{1-\alpha} \tag{6}$$

where A is aggregate productivity (a scale factor). Since the production function has constant returns to scale, we can restrict the size of all plants to be equal to one unit of capital.[12] Recall from equation (5) that, with a slight abuse of notation, $k_t^0(\theta)$ represents the density of plants with embodied productivity θ_t at the begining of the period. This is the measure of plants actively producing in every period, while $k_t^1(\theta)$ is the measure of plants that have not been scrapped at the end of the period. Thus, from now on the reader must bear in mind that $k_t^i(\theta)$ refers to density measures rather than actual units of capital. In addition, we assume that capital depreciates at δ during production. Alternatively, one can interpret δ as an exogenous exit rate, in the sense that in every period a measure δ of plants at each productivity level vanishes. Both interpretations generate similar aggregate outcomes.[13]

Notice that the firm's problem can be solved in stages. When the morning market has closed, the firm must decide how to allocate workers to each new and incumbent plant. Since the technology exhibits constant returns to scale, the solution to this problem is simply:

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[12] Our model does not have implications for *absolute* plant size or its distribution in the economy. First, since at the entry moment all entrants are homogeneous and face the same uncertainty, all entrants would choose the same size. Second, because we do not consider fixed costs of production or increasing/decreasing returns to scale, entry size becomes irrelevant. As a result, our theory is mute about the size distribution in terms of units of capital; but, because we allow for a continuum of plants, we can still focus on the size distribution in terms of workers, as we do in Section 3.

[13] We thank an anonymous referee for this alternative interpretation.

$$n_t(\theta) = \frac{N_t e^{\theta}}{\bar{K}_t} \tag{7}$$

where $\bar{K}_t = \int_{-\infty}^{\infty} e^{\theta} k_t^0(\theta) d\theta$ is the aggregate effective capital stock and $N_t = \int_{-\infty}^{\infty} n_t(\theta) k_t^0(\theta) d\theta$ is aggregate labor. That is, the firm allocates workers to each plant proportionally to its productivity. Notice that, since the exit probability approaches zero as $\theta \to \infty$, equation (7) implies that the size distribution of plants has a lognormal upper tail. We formally show this statement in the simple model presented in the online appendix.

Using equation (6) and (7), the aggregate production of the firm, and therefore the aggregate production of the economy, is given by:

$$Y_t = A\, N_t^{\alpha} \left(\int_{-\infty}^{\infty} e^{\theta_t} k_t^0(\theta_t) d\theta_t \right)^{1-\alpha} \tag{8}$$

Before going to the evening market the firm must decide which plants to sell and which ones to scrap. When a plant is retired, scrapped capital has salvage value $s < 1$ per unit of capital, regardless of its former productivity. Plants that will remain in operation are sold in the evening market at price $q_t^1(\theta)$ per unit of capital. In equilibrium, asset prices equal discounted expected dividend streams, which in turn depend on current productivity: the larger the productivity of a plant, the higher its price in the evening market. This monotone relationship between the value of the plant and its productivity implies that there is a threshold $\bar{\theta}_t$ such that plants with lower productivity exit the market and those with higher productivity remain in operation. Of course, the marginal plant with productivity level $\bar{\theta}_t$ must have a market value equal to the scrap value of capital. Thus, the threshold $\bar{\theta}_t$ is defined implicitly by the following equation:

$$s = q_t^1(\bar{\theta}_t) \tag{9}$$

In the aggregate, the total amount of salvaged capital in period *t* is

$$S_t = (1-\delta) s \int_{-\infty}^{\bar{\theta}_t} k_t^0(\theta) d\theta \tag{10}$$

Finally, the purchase price of a unit of capital at the beginning of the period is determined not only by its marginal product but also by the price at which capital, after depreciation, may be sold at the end of the period. Thus, the zero profit condition dictates the price of capital for each θ_t at the beginning of the period:

$$q_t^0(\theta) = (1-\alpha)\left[\frac{\bar{K}_t}{N_t}\right]^{-\alpha} e^{\theta} + (1-\delta)[1\{\theta < \bar{\theta}_t\}s + 1\{\theta \geq \bar{\theta}_t\}q_t^1(\theta)] \qquad (11)$$

where $1\{\cdot\}$ is an indicator function that equals one if its argument is true and zero otherwise. Note that the information set changes between periods, not inside the period. That is why the law of motion in equation (11) is deterministic and does not involve expectations.

2.4 Constructing new plants

There is an intermediary that takes resources provided by consumers and transforms them into new plants embodied with the leading edge technology. Specifically, in the time sequence of the model, the intermediary receives the resources at the end of the period, constructs plants between periods, and delivers them at the beginning of the next period. Assume that for each new plant, the intermediary must pay π units of the consumption good (per unit of capital) to the government, where π is independent of the productivity of the particular plant. This cost captures the impact of entry barriers such as legal fees, government permits, and bureaucratic procedures, whose cost enterprises must bear regardless of their potential productivity. The government's revenues from entry costs are rebated back to the consumers as lump-sum transfers.[14]

Profit maximization requires that the price of constructing a plant to be equal to the cost of inputs:

$$q_t^c = 1 + \pi_t \qquad (12)$$

This is the ex-ante price of a unit of capital installed in a plant, paid by consumers before the realization of the productivity shock. It includes both the cost of capital and the entry cost. Once in the hands of consumers, the new plants receive the technology shock.[15]

A competitive equilibrium in this economy is a set of decision rules $\{c_t, I_t, \{k_t^0(\theta), k_t^1(\theta), n_t(\theta), y_t(\theta)\}_{\forall\theta}\}_{t=0}^{\infty}$, aggregate allocations $\{I_t, Y_t, N_t, S_t, \overline{K}_t\}_{t=0}^{\infty}$, prices

[14] This is a conservative assumption based on the notion that bureaucratic costs fund wages to public and private sector workers. In practice, some of these costs represent pure waste.

[15] The assumption that the consumers are the investors is without loss of generality. We could consider an alternative and equivalent setup wherein the firm orders new plants, with exactly the same results.

$\{\omega_t q_t^c, \{q_t^0(\theta), q_t^1(\theta)\}_{\forall\theta}\}_{t=0}^{\infty}$, and thresholds $\{\bar{\theta}_t\}_{t=0}^{\infty}$ such that, given transfers $\{T_t\}_{t=0}^{\infty}$, entry taxes π_t, salvage value *s*, and stochastic technology processes $\{\theta_t\}_{t=0}^{\infty}$ and z_t, at each period *t*:

i) The representative consumer chooses consumption and leisure, given initial capital holdings, to solve:

$$\max \sum_{t=0}^{\infty} \beta^t \left[\log(c_t) + \kappa(1 - n_t)\right]$$

$$\text{s.t: } c_t + I_t q_t^c + \int_{-\infty}^{\infty} q_t^1(\theta) k_t^1(\theta) d\theta = \omega_t n_t + \int_{-\infty}^{\infty} q_t^0(\theta) k_t^0(\theta) d\theta + T_t$$

$$k_{t+1}^0(\theta_{t+1}) = \int_{-\infty}^{\infty} \frac{1}{\sigma_\theta} \phi\left(\frac{\theta_{t+1} - \theta_t}{\sigma_\theta}\right) k_t^1(\theta) d\theta + \frac{1}{\sigma_z} \phi\left(\frac{\theta_{t+1} - z_t}{\sigma_z}\right) I_t$$

$$k_t^1(\theta_t) = (1 - \delta) k_t^o(\theta_t) \; if \; \theta_t \geq \overline{\theta}_t \, , \; and \;\; k_t^1(\theta_t) = 0, \; otherwise$$

$$k_0^0(\theta_0) > 0$$

ii) The firm that produces the consumption good satisfies,

$$n_t(\theta) = \frac{N_t e^\theta}{\bar{K}_t}$$

$$\omega_t = \alpha A \left[\frac{\bar{K}_t}{N_t}\right]^{1-\alpha}$$

$$s = q_t^1(\bar{\theta}_t)$$

$$q_t^0(\theta) = (1 - \alpha) \left[\frac{\bar{K}_t}{N_t}\right]^{-\alpha} e^\theta + (1 - \delta)[1\{\theta < \bar{\theta}_t\} s + 1\{\theta \geq \bar{\theta}_t\} q_t^1(\theta)]$$

iii) The intermediary that produces new plants satisfies,

$$q_t^c = 1 + \pi_t$$

iv) The government satisfies the budget constraint,

$$T_t = I_t \pi_t$$

v) Markets clear,

$$c_t + I_t = Y_t + S_t \tag{13}$$

2.5 The complementarity of reforms

In order to understand the sources of complementarities, we analytically solve a simpler version of the model, sketched below and derived fully in the paper's online Appendix. We make two simplifying assumptions: (1) the aggregate technology does not grow and (2) the exit rate is independent of productivity. To this end, instead of assuming that the incumbent's productivity follows a random walk, as in equation (3), we assume that with probability $\rho \in (0,1)$ the incumbent maintains its current productivity, while with probability $(1-\rho)$ it receives a new draw with density $\phi(\theta)$. This simpler economy helps us to formally define and provide the intuition for the main result of our paper, on the complementarity of reforms.

In this simple version of the model, the exit threshold, $\bar{\theta}$ and the investment in new plants are fully characterized by equations (14) and (15). The entry threshold is mainly determined by:

$$e^{\bar{\theta}} = \frac{\beta(1-\beta\rho)s - (1-\rho)(1+\pi)}{\beta\rho r} \tag{14}$$

In equation (14) we see the complementarity of reforms at play.[16] The complementarity can be direct or indirect through equilibrium prices. First, keeping r fixed, the exit threshold is not only determined by the exit cost but also by the entry cost. In the extreme, as $\pi \rightarrow \infty$ the exit threshold is completely determined by the entry cost, and changing s would have little or no impact on the exit probability of plants. The indirect effect comes through$r$, the average marginal return on capital. Because the marginal productivity of capital is decreasing in K, highly distorted economies would have low K and, therefore, high r. As $r \rightarrow \infty$ ($K \rightarrow 0$), the effect on the threshold of changing s vanishes. Note that this indirect complementarity effect is not only related to entry costs but also to any other distortions in the economy that depress the average return of capital. From this point of view the focus of this paper on entry and exit barriers can be seen as a particular implication of a more general problem.

In turn, the measure of entrants, and therefore the average return on capital, is mainly determined by:

[16] Note that one could interpret these findings as substitutability of distortions. Equation (14) shows that keeping r fixed, there are different combinations of high s and low π (and vice versa) that generate the same distorted value for the threshold. In this sense the barriers are substitutes for each other. Complementary reforms are necessary to address substitutable distortions.

$$\left(\frac{r}{1-\alpha}\right)^{-\frac{1}{\alpha}} = \frac{I e^{\frac{1}{2}}(1-\rho\Phi(\bar{\theta}))}{(1-\rho)\Phi(\bar{\theta})(1-\alpha)^{\frac{1}{\alpha}}} \cong \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})]}{e^{\frac{1}{2}}\left(1-\beta\rho\Phi(\bar{\theta})\right)} - s\beta^2\right]^{-\frac{1}{\alpha}} \quad (15)$$

The need for complementary reforms can be analyzed in equation (15) in a similar fashion as in equation (14). For instance, if s is sufficiently low, such that $\bar{\theta} \to -\infty$, and therefore $\Phi(\bar{\theta}) \to 0$, the impact of changing the entry barrier, π, on the investment in new plants, I, is nil. That is, the exit barrier nullifies the entry reforms.

As we show in the online appendix, this simple model can illustrate some mechanisms but can also generate counterfactual comparative statics. For instance, it predicts that the economy's average productivity is independent of entry and decreasing in exit. The full model – adding the adoption of a growing technology and the incentives for exit—can generate the right comparative statics and reinforce the interaction of barriers.

3. Calibration

We analyze steady states under alternative impediments or distortions to the entry and exit margins. To approximate actual experience and to assess the robustness of the results, we simulate equilibria for a wide range of policy values. We solve for equilibria numerically using a three-step strategy. First, we compute the steady-state equilibrium. Second, we log-linearize the system of equations that characterize the solution around the long-run values of equilibrium elements. Finally, we use the method of undetermined coefficients described in Christiano (2002) to recover the coefficients of the individual policy functions. Because the economy exhibits unbounded growth in all variables other than labor, we scale the non-stationary variables by the long-run (gross) growth rate, and then use a mapping to take the solution from the scaled objects used in the computations to the un-scaled objects of interest.

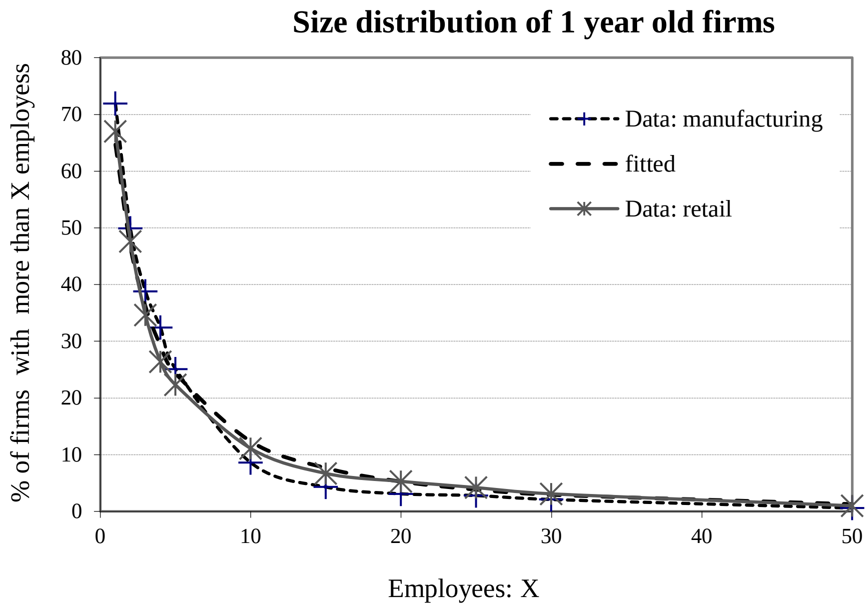
We separate the parameters into aggregate parameters $\{\beta, \alpha, \mu, \kappa, \delta\}$, plant specific parameters $\{\sigma_\theta, \sigma_Z\}$, and distortions $\{\pi, s\}$. Most aggregate parameters are calibrated as in a representative firm economy. As it is standard in the RBC literature we use a discount factor of $\beta = 0.96$. The share of labor income to output is set at $\alpha = 0.7$, following Gollin (2002). Long-run growth is given by $\mu(1-\alpha)/\alpha$, which, since the population is stationary, also represents the growth rate of income per capita. Thus, to have a trend growth rate of 2 percent per year, we set μ equal to 4.5 percent. The marginal utility of leisure, κ, determines the fraction of available time allocated to labor. We choose κ so that the fraction of hours worked, N, equals 0.33 in steady state.

The parameter values just mentioned are similar to those in the standard macroeconomic literature. The calibration of the depreciation rate and standard deviation of technological shocks, however, deserves more discussion. In a representative firm model, the depreciation rate is typically set around 6 percent per year, representing the exogenous loss in the value of capital occurring over time. This loss happens for two reasons: Wear-and-tear and technological obsolescence. In our environment this approach is no longer valid since we explicitly include a rate of technological obsolescence, which is determined by both s and the exit rate. Therefore, in our economy δ captures only the deterioration of capital goods due to usage. Furthermore, the standard deviations of plant productivity shocks are key determinants of entry and exit rates. The standard deviation of the productivity of entrants, σ_z, has a first order effect on the entry rate: the more uncertain the result of investment in a new project, the lower the investment; everything else equal, there is a negative relationship between entry and σ_z. Similarly, there is a positive relationship between the standard deviation of the incumbents' productivity, σ_θ, and exit: the more uncertain the current level of productivity, the lower the value of an incumbent firm and, therefore, the larger the exit rate.

Since our main focus is on the aggregate effects of alternative policies, we choose these parameters $(\delta, \sigma_z, \sigma_\theta)$ to match aggregate investment (entry) and salvage capital (exit). First, note that since the steady state level of capital is given by $K = (I - S)/\delta$, targeting S (the aggregate salvage value, which is not directly observed) can be replaced by targeting K (along with I). Second, note that we have three parameters to match two moments; and then, to differentiate σ_z from σ_θ, we also target the size distribution of entrants. Therefore, the parameters σ_z and σ_θ are chosen to match the size distribution of entrants, the ratio of aggregate investment to gross domestic product (GDP), and the capital output ratio simultaneously.

Notice that equations (4) and (7) imply that the size distribution of entrants (in terms of labor units) is lognormal. Pakes and Ericson (1998) shows the size distribution of firms by age in the retail and manufacturing sectors for the U.S. economy. We define one-year-old firms in the retail sector as entrants, assume that their size distribution is lognormal, and look for the standard deviation that best fits the observed distribution. Figure 2 shows the observed size distribution of entrants in the retail and manufacturing sectors, as well as the calibrated distribution of entrants in the model. The fit of the calibrated to the actual distribution is quite reasonable.

Figure 2: Observed and calibrated distributions of entrants' size



The investment rate in the U.S. is around 22 percent of GDP, and the capital output ratio is about 3. Putting this information together with the standard deviation of entrants' size, we generate parameter values of σ_θ = 0.375, $\sigma_z = 1.31$ and δ=0.025. Note that this depreciation value is similar to the depreciation rate reported in the U.S. for housing, where technological obsolescence is of minor importance. Also, note that the calibrated σ_z implies that entrants are predominantly small in terms of employment, with a mean number of employees of around 5 and a median of around 2 (the ratio of mean to median being a constant depending on the log normal distribution of employment).[17]

[17] Since σ_θ is not targeting any firm's specific moment (but is derived jointly with δ and σ_Z), one may wonder how the model's economy performs regarding the size distribution of firms (which most closely relates to the distribution of incumbents' productivity shocks). In order to assess this, we follow Luttmer (2007) constructing the joint density by productivity and age of firms in our calibrated economy. The results (not provided in the paper but available on request) indicate that in general the model replicates the size distribution of firms at different ages fairly well, except that our calibration slightly underestimates the growth rates of firms.

Finally, we calibrate the indicators of entry and exit distortions, π and s, to match data from the World Bank *Doing Business* database. Two specific indexes are of interest: The cost of starting a business and the recovery rate after bankruptcy. There are large differences in entry and exit costs across economies. Table 2 provides selected summary statistics on entry barriers and recovery rates in 183 countries included in the *Doing Business* database. It also presents the values corresponding to the U.S. and the median less-developed country (LDC) according to income per capita, which in the late 2000s was Egypt.

The most entry-regulated economies (90th percentile) have a direct monetary cost to start a business of about 200 percent of GDP per capita, about 60 times larger than the cost of the least entry-regulated economies (10th percentile). Recovery rates after exit are 0 percent and 75 percent for the 10th percentile and 90th percentile countries, respectively.

Table 2: Selected statistics of entry costs and exit recovery rates

	Entry		Exit
	Fees (% of GDP pc)	Time (days)	Recovery rate (cents per 1$)
Average	106.3	46.2	30.8
Median	24.3	34.6	27.3
Minimum	0.0	2.0	0.0
Maximum	6,375.5	694	92.7
St. Deviation	491.3	59.6	24.9
P90	203.9	87.5	75.3
P10	3.21	11.7	0.0
U.S.	0.8	6.0	77.5
Median LDC, by GDP	68.8	19.0	17.5

Source: World Bank, *Doing Business*, various years

There is a direct link between the recovery rates from *Doing Business* and the parameter s in the model. Both represent the fraction of initial investment that is recovered and available for new capital formation when the firm closes. Granted, the recovery rate from *Doing Business* does not represent the full value of physical capital at bankruptcy since it focuses on creditors' rights. Nevertheless, it is consistent with what we attempt to capture in the model. The parameter s does not intend to represent the resale value of physical capital: If it is still in use and only changing ownership, it continues to be considered as incumbent capital. In the model, s represents the value that can reenter the economy after bankruptcy to fund new capital, and this is consistent, albeit not perfectly, with the *Doing Business* measure.

The mapping between the entry barrier data from *Doing Business* and the parameter π in the model is more involved. First, we need to convert the two measures of the cost of starting a business, fees and time, into the same unit. As an approximation, we do it by assuming that the fraction of days in a year that it takes to open a business corresponds to the fraction of GDP per capita lost in the process. We add this measure to the fees, already expressed as a ratio to GDP per capita. Second, we need to transform this cost from units of GDP per capita to units of the consumption / capital good. This is not straightforward because the entry cost as a ratio to GDP per capita is endogenous, depending among other things on the prevailing recovery rate, s. Thus, for each country, we find π such that the generated π/GDP ratio is equal to the one observed in the data. For instance, for the U.S., with about 0.02 of GDP as entry barrier and 0.775 recovery rate, we would have $\pi \approx 0$. Table 3 displays the resulting parametric specification for the U.S., our benchmark economy.

Table 3: Parametric specification

Aggregate parameters		**Parameter**	**Value**
Discount factor		β	0.96
Fraction of steady state hours worked		N	0.33
Labor share		α	0.70
Depreciation rate		δ	0.025
Leading edge technology drift		μ	0.045
Plant level parameters			
St. deviation of shock to incumbents		σ_θ	0.375
St. deviation of shock to startups		σ_z	1.310
Simulation parameters			
U.S.:	Recovery rate	s	0.775
	Entry barrier	π	0

Admittedly, the mapping between these indexes and the model's parameters, π and s, is not exact; we also acknowledge that the indicators from *Doing Business* are neither complete nor exclusive proxies of the model's parameters. However, for the purpose of the interpretation of the model, they are the best in terms of representing distortions to entry and exit margins for a large sample of countries. The estimated output gaps generated by the model should be taken with caution, especially because they depend on the absolute values estimates for the entry and exit barriers. Nonetheless, as we explain in more detail in Section 4, the main finding of this paper -- the existence of large complementarities -- is robust to the choice of the recovery rate, s, for the benchmark economy. In Appendix II we show that the explanatory power of the model is robust to a measure of s for LDCs built from data on firing costs.

Table 4: Quantitative implications for the calibrated economies of the U.S. and developing countries

	Median LDC by GDP per capita	US
Investment/GDP (%)	5.9	22.0
S/GDP **(%)**	0.4	13.1
K/GDP	2.44	3.01
TFP (relative to the U.S.)	0.72	1
Average Productivity, $\bar{K}_t$ (relative to the U.S.)	0.44	1
Proportion of entrants that exit the same year (%)	8.2	68.1
Proportion of firms exiting (%)	1.5	8.2
Proportion of exiting workers in entrants (%)	0.3	19.2
Proportion of exiting workers (%)	0.008	0.8
Mean incumbent size (employment) /mean entrant size	11.0	10.9

Table 4 shows some quantitative implications for the calibrated economies of the U.S. and a representative developing country -- the median LDC by GDP-per-capita-weighted distortions. The first point to note is that the U.S. economy has substantially higher rates of entry and exit than the economy of a typical developing country. Second, the U.S. has higher TFP and average productivity, with the difference regarding average productivity being larger. Third, there are large rates of failure for entrants, especially in the U.S. economy, but their impact on employment is relatively small; due to exiting firms' low productivity, they account for a small fraction of either total employment or employment in newly created firms. Third, the average ratio of the size of incumbents to that of entrants in terms of employment is relatively the same across the two economies, despite wide variations in entry and exit rates.[18] We further discuss these issues in Section 5.

[18] Our calibration implies that incumbents are, on average, around 11 times larger than new firms in terms of employment. Pakes and Ericson (1998) find that incumbents are 12.5 times larger than one-year old firms in the manufacturing sector and 3 times larger than one-year old firms in the retail sector.

4. Results

We now analyze the implications of entry and exit distortions on long-run output and discuss the economic mechanism in play. Then, we quantify its empirical relevance by measuring observed output gaps between the U.S. (our benchmark efficient economy) and a large sample of developing countries (the inefficient economies in the model).

4.1 The economic mechanism

In order to illustrate the potential impact that barriers to technological adoption could have on long-run output differences across countries, we simulate the steady-state output relative to the U.S. for a large set of possible entry and exit barriers. The simulated economies are alike in all respects but their entry and exit costs. The results are illustrated in Figures 3.a and 3.b, where we plot the effect of entry barriers (Figure 3.a) and of recovery rates (Figure 3.b), for four different values of the other parameter.

Figure 3.a
Output Relative to Efficient Economy (U.S.) as function of Entry Barrier (π)
given different recovery rates (s)

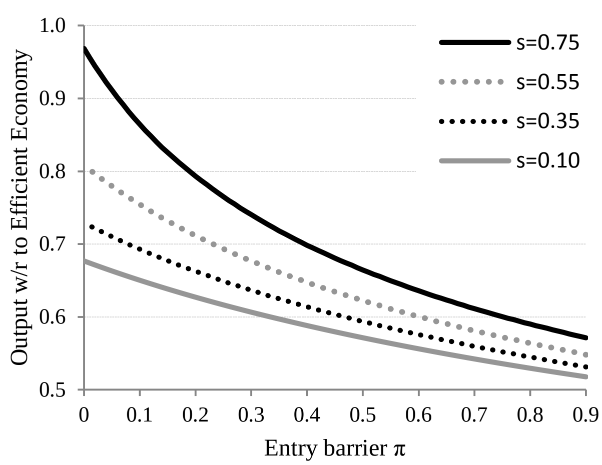
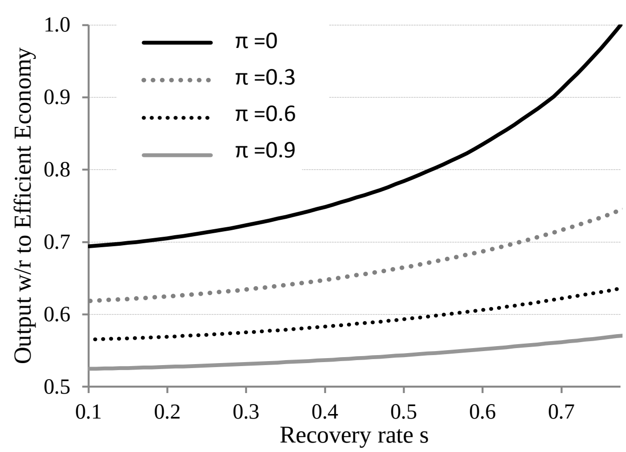


Figure 3.b
Output Relative to Efficient Economy (U.S.) as function of Recovery Rate (s)
given different entry barriers (π)



Notes:
1. Output denotes GDP per capita

Three conclusions should be highlighted. First, worsening entry barriers (higher π) or recovery rates (lower s) decreases steady-state output monotonically. Overall, the model generates substantial output heterogeneity, not reaching however the actual diversity across countries in the world: With respect to the efficient economy ($\pi = 0$ and $s = 0.775$), worsening entry barriers or the recovery rate can lead to output being as little as 50 percent of that of the benchmark economy. Second, the output effect of reducing each barrier decreases with the size of the barrier: If the economy is much distorted, only large reductions of entry or exit barriers will have an important effect on output. Third, there is a reinforcing interaction between entry and exit barriers (reflected in the panels of Figure 3 by the larger slopes of each curve for lower values of the excluded distortion). Increasing the recovery rate when entry barriers are kept at high levels has almost no impact on GDP per capita. (For instance, in Figure 3.b, when s increases from 0.6 to 0.775, output as a fraction of the benchmark value jumps from 84 to 100 percent if $\pi = 0$ but only rises from 55 to 56 percent if $\pi = 0.9$.) Similarly, reducing entry barriers when the economy exhibits high exit costs, has only a small impact on GDP per capita.

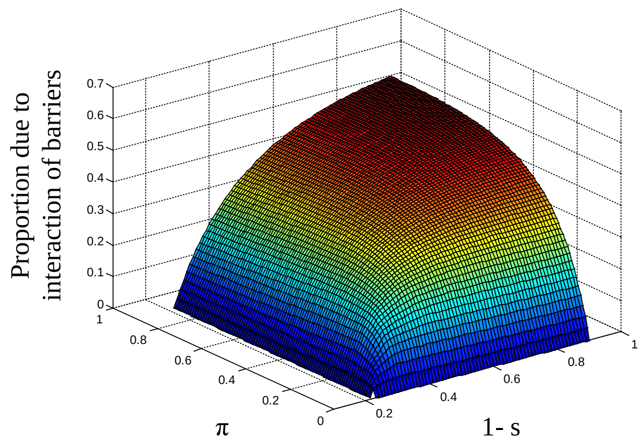
From these results, a policy implication follows: Only comprehensive reforms can have substantial effects. If they are narrow (focusing on only one margin) or mild (leaving in place a large distortion), microeconomic reforms for firm renewal are unlikely to have important effects on aggregate output.

Figure 4 illustrates the features and quantitative relevance of the reinforcing interaction between distortions in more detail. The figure shows the fraction of the steady-state output gap that can be accounted for by the interaction of distortions, for a wide range of values for the entry and exit costs.[19] Two points should be underscored. First, the relative importance of the interaction in explaining output gaps increases as the barriers worsen. The implication is that when the economy suffers from large distortions, it is especially important to conduct joint reforms that address all relevant margins. Second, the contribution of the interaction effect grows rapidly as barriers arise and amounts to between 30 and 50% for most combinations of π and s. This implies a certain degree of robustness of the interaction effect across different distortion parameters. Appendix II shows that the degree of interaction is also robust to a theoretical specification in which recovery rates are replaced by labor firing costs.

[19] The output gap is measured as the proportional difference in GDP generated by each combination of s and π with respect to the benchmark economy. The proportion of this gap due to the interaction of barriers, as measured in the vertical axis of Figure 4, is the remaining fraction after subtracting the output gap due to π given s in the benchmark economy and the output gap due to s given π in the benchmark economy.

Figure 4: The interaction effect is more important when barriers are larger

Fraction of output gap explained by the interaction of entry and exit barriers



To shed further light on the mechanisms underlying the effect of entry and exit barriers and of their interaction, we attempt to separate the roles of sheer capital accumulation and technological improvement in explaining output gaps.[20] If the number of working hours per person is constant, differences in GDP per capita generated by the model are only due to effective capital, $\overline{K}_t$. We can decompose this variable into two components: the stock of capital uncorrected for productivity (measured using the standard perpetual inventory method, with $K = (I - S)/\delta$ in steady state), and the implied TFP (measured as the Solow residual). Then, we can simulate the estimated GDP gap with respect to the efficient economy *and* the portions due to capital and TFP for various values of entry and exit costs. A selection of the results is graphed in Figures 5 and 6.

From Figure 5, we first note that TFP is more important than capital in explaining output gaps for the large majority of possible values of entry barriers and recovery rates (nearly 80% to be precise). In addition, TFP is more important than capital especially when the exit distortion is high but the entry barrier is low. We conjecture that the low productivity of incumbents explain the larger importance of TFP gaps when entry is relatively unencumbered while exit is delayed. On the other hand, the importance of capital gaps is larger when entry barriers are high and exit

[20] We should, however, warn that this decomposition exercise is only speculative since in our model technological improvements are embedded in new capital.

distortions low, suggesting that an insufficient number of entrants may be behind the output gap in this case.

Figure 5.a

Output Gap Relative to Efficient Economy
Relative Importance of TFP and Capital
as function of the entry barrier (π)

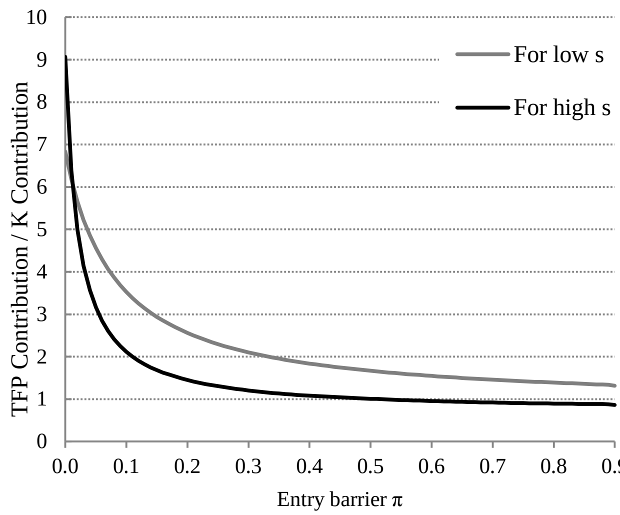
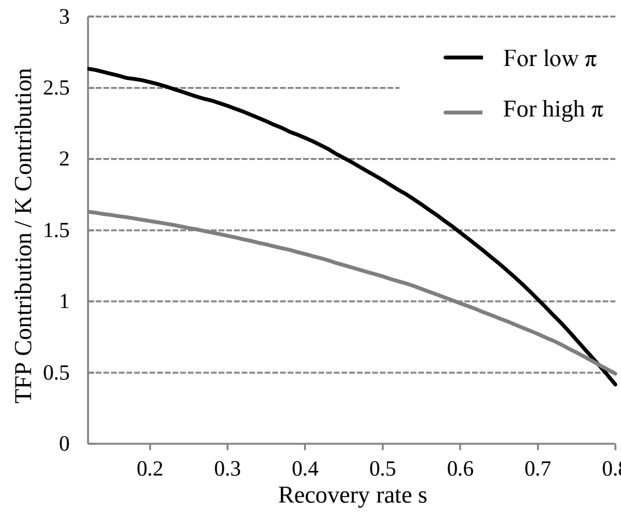


Figure 5.b

Output Gap Relative to Efficient Economy
Relative Importance of TFP and Capital
as function of the recovery rate (s)



Notes::
1. The vertical axes are presented in absolute numbers representing the ratio of TFP contribution to K contribution
2. High π = 0.68, low s = 0.27: High entry and exit distortions, respectively
3. Low π = 0.23, high s = 0.61: Low exit and entry distortions, respectively
4. Output denotes GDP per capita
5. Output gap is computed as $\frac{Output_{US} - Output_i}{Output_{US}}$ Output denotes GDP per capita

Figure 6 allows us to see whether the source of the interaction between entry and exit barriers is the sheer amount of capital or TFP. We plot the output gap due to capital and the output gap due to TFP against the entry barrier π (Figure 6.a) and the recovery rate s (Figure 6.b). We then compare the slopes for two different values o the barrier not represented in the horizontal axis. (For instance, in Figure 6.a, we plot curves corresponding to high and low recovery rates and then compare their slopes. This is analogous to the exercise presented in Figure 3.) Focusing on variations along the entry barrier, we observe that the slopes corresponding to both capital and TFP are larger (in the direction of closing the output gap) when the recovery rate s is higher. This implies that as the entry distortion is reduced, *more and better* entrants' capital can play a larger beneficial role when exit is more attractive. Focusing on variations along the recovery rate (Figure 6.b) we note that only the slope corresponding to TFP is larger (in the direction of closing the gap) when the entry barrier π is lower. This suggests that as the exit distortion is reduced, there is a stronger *shift in composition* from less productive incumbents to more productive entrants when entry is easier.

Figure 6.a

Output Gap Relative to Efficient Economy
Due to TFP and Capital
as function of the entry barrier (π)

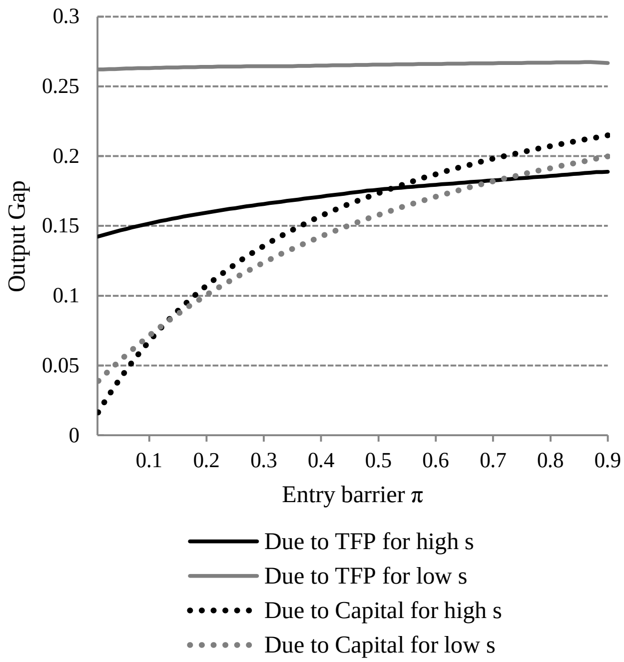
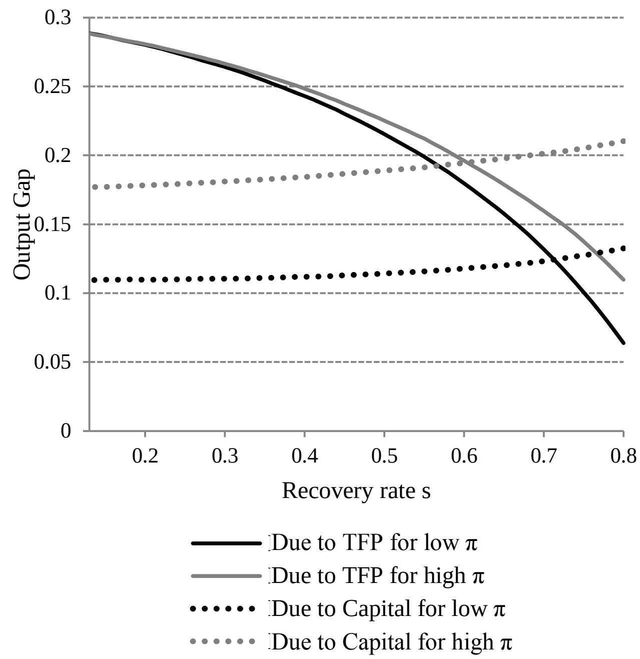


Figure 6.b

Output Gap Relative to Efficient Economy
Due to TFP and Capital
as function of the recovery rate (s)



Notes:

1. High π = 0.68, low s = 0.27: High entry and exit distortions, respectively
2. Low π = 0.23, high s = 0.61: Low exit and entry distortions, respectively
3. Output denotes GDP per capita
4. Output gap is computed as $\frac{Output_{US}-Output_i}{Output_{US}}$ Output denotes GDP per capita

4.2 Explaining long-run per capita output gaps across countries

To assess the model's ability to account for observed income differences given a country's estimated entry cost and recovery rate, we simulate its predicted output gap with respect to the U.S. That is, for each developing country in our sample, we measure the output the U.S. would lose if it had the country's higher entry and exit costs. In addition, we measure the contribution of each distortion separately and of their interaction in explaining the simulated output gap.

Appendix I presents the results for 107 developing countries, and Table 5 provides a summary, focusing on typical developing countries in various regions (medians according to

GDP per capita). Two results deserve special attention. First, despite the model's narrow emphasis on growth through technology adoption and firm renewal, and given the estimated entry and exit costs, its mechanism can generate a substantial fraction of the GDP per capita gap between the U.S. and each developing country, ranging from 26 to 60% for the full sample. Considering the full sample of developing countries, the median share of explanatory power is 49%.

Table 5: Explaining Long-Run Output Gaps

Region	Recovery Rate (s)	Entry Barrier (π)	Percentage Simulated Over Actual Output Gap*	Percentage Contribution to Simulated Output Gap		
				s	π	interaction
East Asia and Pacific (China)	0.325	0.170	38%	48%	16%	35%
Europe and Central Asia (Serbia)	0.225	0.140	44%	56%	12%	32%
Latin America & the Caribbean (Colombia)	0.557	0.290	39%	22%	42%	35%
Middle East and North Africa (Jordan)	0.275	0.570	48%	18%	31%	51%
South Asia (Pakistan)	0.400	0.240	36%	36%	24%	40%
Sub-Saharan Africa (Tanzania)	0.225	0.720	47%	14%	33%	53%
World – Developing Countries (Egypt)	0.175	0.550	49%	20%	27%	52%

Notes:

1. Data reported corresponds to the median country in each region by GDP per capita.
2. Countries with a population smaller than 1 million were excluded when selecting the median.

* Estimated output gap obtained from the model as a percentage of the actual output gap. Output gap is computed as $\frac{Output_{US} - Output_i}{Output_{US}}$. Output denotes GDP per capita.

Second, the model implies that a large fraction of the estimated GDP per capita gap is explained by the interaction between entry and exit barriers. Considering the full set of countries, shown in Appendix I, the model indicates that between 20 to 56% of the estimated gap is explained by the interaction of barriers and the rest by each barrier separately. Considering the median developing countries in all regions, shown in Table 5, the interaction between barriers explains between 32% and 53% of the gap. For the median LDC the interaction accounts for 52% of the estimated gap.. As suggested in the previous section, the quantitative importance of the interaction effect is robust to a wide range of distortion values: limiting to the interquartile range for both entry and exit barriers, the interaction effect accounts for between 37 and 54% of the estimated gap.

5. Conclusion

This paper links microeconomic rigidities and technological innovation to propose a partial explanation for the observed differences in income per capita across countries. Countries where firm renewal is more active are able to adopt new technologies with greater ease, which makes them more productive and allows them to grow faster. Since new technologies are developed always, countries that are able to adopt and adapt them continuously and forcefully will become constantly richer than those where technological adoption is sluggish.

Microeconomic rigidities refer to developmental and institutional conditions that interfere with the natural process of entry, growth, and exit of firms. By distorting incentives, microeconomic rigidities can slow down the process of firm renewal, with detrimental impact on aggregate productivity and output growth. This paper highlights the role of entry and exit barriers. It argues that as these barriers become more burdensome, the distribution of firms in the economy is altered: Too many inefficient firms remain and too few efficient firms enter. Both the reallocation of resources from less to more efficient firms and the adoption of the leading edge technology are slowed down. Although new technologies are eventually implemented, the difference in the speed at which they are adopted is what accounts for income disparities.

The paper also argues that there are important nonlinearities in the way entry and exit barriers operate. First, barriers have increasing costs in terms of output loss. That is, the negative impact of each barrier grows with the size of the barrier itself. Second, barriers reinforce each other's negative impact. And this interaction is more important when barriers (and distortions) are large. From these results, an important policy implication follows: Only comprehensive reforms can have substantial effects, especially when initial distortions are large. If they are too narrow (focusing on only one barrier) or too mild (leaving in place a large distortion), microeconomic reforms for firm renewal are unlikely to have important effects on aggregate productivity and output growth.

As its title implies, the paper emphasizes the importance of complementary reforms. Correspondingly, much of the paper is devoted to illustrating and understanding the interaction between barriers that underlies this complementarity. In the model, the interaction arises because there is a direct, two-way link between entry and exit through the incentives for technological adoption. Technological adoption requires new investment and entry; entry (of more productive projects) requires resources and competitive conditions in the market, both of which are facilitated by exit (of less productive incumbents); and, in turn, exit requires attractive conditions for reentry. In this context, ease of entry makes dropping old and less productive projects more appealing; and ease of exit releases resources that can be used for new projects and makes market conditions more attractive for entrants.

We note two shortcomings of our paper. First, a more encompassing study of microeconomic rigidities would also take into account barriers derived from lack of human capital, poor public infrastructure, and financial constraints. They are implicit in our model but not taken into account in its empirical implementation. They are bound to exacerbate the contractual and adaptation costs of new technologies (see, for instance, Acemoglu and Zilibotti, 2001). Second, a more rigorous calibration of microeconomic dynamics would match accurately production units in the model and in the data. We have loosely referred to firms, plants, and projects as production units. This is fine for a theoretical model, but more strict definitions are needed for accurate empirical calibration and simulation. This is especially important when studying innovation and distortions related to entry and exit, where defining *who* enters or exits is essential (see Acemoglu and Cao, 2010, for a discussion of related technical difficulties).

Finally, we hope to encourage more research regarding the timing of reforms. Economic reforms have been undertaken by many developing economies during the last 25 years. However, most reforms are implemented in a piecemeal fashion, so that when some obstacles are removed others remain. For lack of results, fragmentary reforms are eventually reversed. Our paper implies that economic reforms can be made sustainable and their benefits substantially improved if they are implemented jointly, or at least addressing all relevant margins.

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Appendix I: Explaining Output Differences between the U.S. and Developing Countries

Country	Recovery Rate (s)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution to Simulated Output Gap		
					s	π	interaction
Algeria	0.425	0.180	0.32	39%	43%	21%	36%
Angola	0.100	0.900	0.49	55%	12%	33%	56%
Argentina	0.350	0.180	0.34	47%	46%	18%	36%
Armenia	0.425	0.090	0.29	33%	63%	13%	24%
Azerbaijan	0.325	0.200	0.35	42%	44%	18%	38%
Bangladesh	0.250	0.500	0.42	43%	21%	28%	50%
Belarus	0.325	0.370	0.39	51%	27%	27%	46%
Belize	0.625	0.570	0.39	45%	8%	61%	31%
Benin	0.225	0.900	0.48	50%	11%	36%	53%
Bolivia	0.375	0.900	0.47	52%	9%	43%	48%
Bosnia and Herzegovina	0.350	0.410	0.39	47%	23%	30%	47%
Botswana	0.600	0.360	0.33	47%	16%	50%	34%
Brazil	0.125	0.400	0.41	53%	28%	22%	50%
Bulgaria	0.350	0.150	0.33	43%	51%	16%	33%
Burkina Faso	0.275	0.900	0.48	49%	10%	38%	52%
Cameroon	0.250	0.900	0.48	50%	10%	37%	53%
Chile	0.225	0.150	0.35	50%	54%	12%	33%
China	0.325	0.170	0.34	38%	48%	16%	35%
Colombia	0.557	0.290	0.32	39%	22%	42%	35%
Congo, Dem. Rep.	0.100	0.900	0.49	49%	12%	33%	56%
Congo, Rep.	0.200	0.900	0.48	52%	11%	35%	54%
Costa Rica	0.175	0.350	0.4	53%	31%	21%	48%
Cote d'Ivoire	0.350	0.900	0.47	49%	9%	42%	49%
Djibouti	0.150	0.900	0.48	51%	11%	34%	55%
Dominican Republic	0.100	0.390	0.41	50%	29%	21%	50%
Ecuador	0.175	0.390	0.41	49%	28%	23%	49%
Egypt, Arab Rep.	0.175	0.550	0.44	49%	20%	27%	52%
El Salvador	0.300	0.620	0.44	51%	16%	34%	51%
Ethiopia	0.325	0.400	0.39	40%	25%	28%	47%
Fiji	0.200	0.310	0.39	43%	34%	20%	46%
Gabon	0.150	0.320	0.4	58%	34%	19%	47%
Gambia, The	0.175	0.900	0.48	50%	11%	35%	54%
Georgia	0.275	0.130	0.34	37%	57%	12%	31%
Ghana	0.250	0.540	0.43	44%	19%	30%	51%
Guatemala	0.275	0.470	0.41	46%	22%	28%	50%
Guinea	0.175	0.900	0.480	49%	11%	35%	54%

Country	Recovery Rate (s)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution to Simulated Output Gap		
					s	π	interaction
Guyana	0.175	0.790	0.470	50%	13%	33%	54%
Haiti	0.100	0.900	0.490	50%	12%	33%	56%
Honduras	0.200	0.550	0.430	47%	20%	28%	52%
India	0.125	0.640	0.450	48%	18%	28%	54%
Indonesia	0.125	0.790	0.470	51%	14%	31%	55%
Iran, Islamic Rep.	0.200	0.110	0.343	45%	63%	9%	27%
Jamaica	0.650	0.120	0.217	26%	38%	38%	24%
Jordan	0.275	0.570	0.430	48%	18%	31%	51%
Kazakhstan	0.400	0.120	0.306	40%	56%	15%	29%
Kenya	0.325	0.480	0.409	42%	20%	31%	49%
Kyrgyz Republic	0.150	0.140	0.358	37%	58%	11%	32%
Latvia	0.350	0.070	0.302	46%	71%	9%	20%
Lebanon	0.200	0.740	0.461	60%	14%	32%	54%
Lesotho	0.375	0.470	0.401	41%	20%	33%	47%
Liberia	0.100	0.900	0.486	49%	12%	33%	56%
Lithuania	0.500	0.100	0.269	42%	57%	18%	26%
Macedonia, FYR	0.150	0.110	0.351	43%	64%	9%	27%
Malawi	0.125	0.900	0.485	49%	12%	33%	55%
Malaysia	0.375	0.240	0.348	49%	37%	23%	40%
Maldives	0.175	0.140	0.355	40%	57%	11%	32%
Mali	0.225	0.900	0.48	49%	11%	36%	53%
Mauritania	0.100	0.900	0.486	51%	12%	33%	56%
Mauritius	0.350	0.180	0.336	45%	46%	18%	36%
Mexico	0.650	0.210	0.263	38%	23%	49%	28%
Micronesia, Fed. Sts.	0.100	0.900	0.486	52%	12%	33%	56%
Moldova	0.300	0.190	0.348	37%	46%	17%	37%
Mongolia	0.175	0.100	0.344	37%	66%	8%	26%
Montenegro	0.425	0.120	0.300	40%	55%	16%	29%
Morocco	0.350	0.140	0.324	36%	53%	15%	32%
Mozambique	0.150	0.810	0.473	48%	13%	32%	55%
Namibia	0.425	0.370	0.372	43%	24%	32%	44%
Nepal	0.250	0.640	0.444	45%	16%	32%	52%
Nicaragua	0.350	0.900	0.472	50%	9%	42%	49%
Niger	0.150	0.900	0.484	49%	11%	34%	55%
Nigeria	0.275	0.510	0.420	44%	20%	30%	50%
Pakistan	0.400	0.240	0.343	36%	36%	24%	40%
Panama	0.325	0.250	0.359	48%	37%	21%	41%
Papua New Guinea	0.225	0.350	0.395	41%	30%	22%	47%
Paraguay	0.150	0.900	0.484	54%	11%	34%	55%

Country	Recovery Rate (s)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution to Simulated Output Gap		
					s	π	interaction
Peru	0.250	0.410	0.404	49%	26%	26%	49%
Philippines	0.100	0.320	0.401	43%	35%	18%	47%
Poland	0.275	0.250	0.367	57%	39%	20%	42%
Romania	0.200	0.070	0.332	44%	74%	6%	20%
Russian Federation	0.275	0.120	0.333	49%	60%	11%	29%
Samoa	0.150	0.430	0.417	46%	26%	23%	51%
Senegal	0.325	0.900	0.474	49%	10%	40%	50%
Serbia	0.225	0.140	0.347	44%	56%	12%	32%
Sierra Leone	0.100	0.900	0.486	49%	12%	33%	56%
Solomon Islands	0.225	0.690	0.453	48%	15%	32%	53%
South Africa	0.350	0.150	0.327	42%	51%	16%	33%
Sri Lanka	0.500	0.210	0.311	34%	35%	29%	36%
St. Lucia	0.425	0.270	0.347	44%	32%	27%	41%
Suriname	0.100	0.900	0.486	57%	12%	33%	56%
Swaziland	0.375	0.460	0.399	45%	20%	33%	47%
Syrian Arab Republic	0.300	0.270	0.368	41%	36%	21%	43%
Tajikistan	0.225	0.680	0.451	47%	15%	32%	53%
Tanzania	0.225	0.720	0.457	47%	14%	33%	53%
Thailand	0.425	0.140	0.307	37%	51%	18%	32%
Togo	0.275	0.900	0.477	49%	10%	38%	52%
Tonga	0.250	0.160	0.349	38%	52%	14%	34%
Tunisia	0.500	0.120	0.278	33%	51%	20%	28%
Turkey	0.175	0.230	0.376	52%	43%	16%	41%
Uganda	0.400	0.760	0.449	46%	11%	42%	47%
Ukraine	0.100	0.150	0.366	43%	56%	10%	33%
Uruguay	0.425	0.450	0.39	52%	19%	36%	45%
Uzbekistan	0.175	0.190	0.367	39%	48%	14%	38%
Vanuatu	0.400	0.560	0.416	45%	16%	37%	47%
Venezuela, RB	0.100	0.480	0.429	59%	24%	24%	52%
Vietnam	0.175	0.310	0.393	42%	35%	20%	46%
Yemen, Rep.	0.275	0.900	0.477	50%	10%	38%	52%
Zambia	0.250	0.320	0.386	40%	32%	22%	46%

* Proportional output gap with respect to the U.S $\left(\frac{Output_{US}-Output_i}{Output_{US}}\right)$ obtained from the model. Output denotes GDP per capita.

Appendix II: Firing costs

In the main body of the paper, we assume that the cost of closing down a plant can be modeled as a capital irreversibility. To further assess the robustness of our result about the importance of interaction effects, we consider an alternative setup where, keeping *s* fixed, we use firing costs as a proxy for exit costs. Now, to close down a plant, a firm has to pay τ additional wages to each worker employed in that plant. The firing cost is incurred only when the plant is shut down, but not when it is downsized.

The extension to the model presented in Section 2 is straightforward. First, notice that there is a one-to-one mapping from productivity level to employment size, given by equation (7), which directly links the number of workers employed in a plant to its productivity. Thus, a firm incurs an additional cost given by $\tau\ \omega\ n(\theta)$ each time it closes down a plant. Using equation (7) and the firm's first order condition for labor and capital, this quantity can be expressed as $\tau \frac{\alpha}{1-\alpha} r\, e^{\theta}$. Therefore, the exit condition in equation (9) becomes:

$$s - \tau \frac{\alpha}{1-\alpha} r\, e^{\bar{\theta}_t} = q_t^1(\bar{\theta}_t) \quad (9')$$

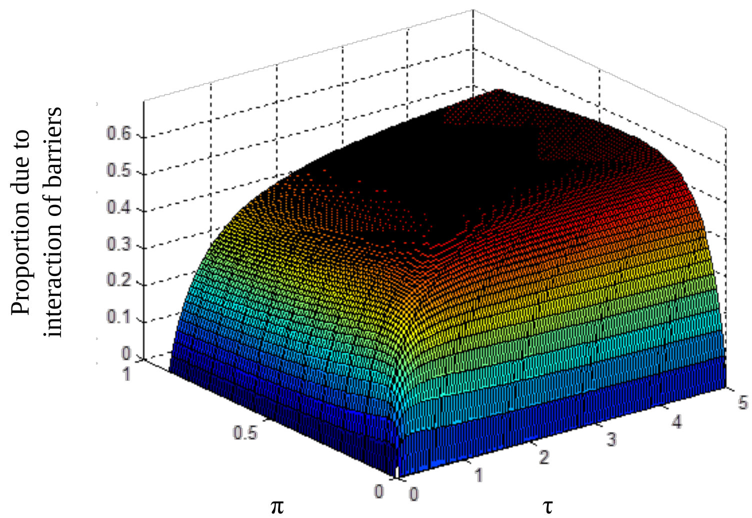
The new exit condition is still monotone in θ, which guarantees the existence of the threshold productivity level. In addition, the firing cost affects the price that the firm is willing to pay in the morning market to operate a plant. Equation (11) is replaced by:

$$q_t^0(\theta) = (1-\alpha)\left[\frac{K_t}{N_t}\right]^{-\alpha} e^{\theta} + (1-\delta)\left[1\{\theta < \bar{\theta}_t\}\left(s - \frac{\tau\, \alpha\, r\, e^{\theta_t}}{1-\alpha}\right) + 1\{\theta \geq \bar{\theta}_t\} q_t^1(\theta)\right] \quad (11')$$

To simulate the new equilibrium, we assume that *s* is the same across countries with a value equal to 0.775, obtained from *Doing Business* for the U.S. The firing costs per country are obtained from *Doing Business* as well, as in Moscoso and Mukoyama (2012). The maximum firing cost in our sample is 3.7 annual wages. In the full data set, 99% of countries have firing costs of less than 5 annual wages. Figure II.1 is analogous to Figure 4, with $(1-s)$ replaced by τ as the exit barrier, with a range of firing costs from 0 to 5 annual wages. Appendix III shows the simulation results for our full sample of LDCs.

The main features from the original model specification remain unchanged. If anything, with firing costs instead of recovery costs, the interaction between barriers accounts for a larger fraction of the development gap.

Figure II.1. Output gap explained by the interaction of entry barriers and firing costs



Appendix III: Explaining Output Differences between the U.S. and Developing Countries with firing costs (τ)

Country	Firing cost (tau)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution: tau	Percentage Contribution: π	Percentage Contribution: complementarity
Algeria	0.327	0.100	0.20	24%	19%	50%	31%
Angola	1.115	0.900	0.45	51%	2%	60%	39%
Argentina	2.673	0.100	0.27	39%	41%	16%	43%
Armenia	0.250	0.060	0.16	18%	27%	47%	26%
Azerbaijan	0.423	0.120	0.22	27%	18%	47%	34%
Bangladesh	2.000	0.290	0.33	34%	14%	35%	51%
Belarus	0.423	0.210	0.27	36%	9%	57%	34%
Belize	0.462	0.310	0.31	37%	6%	61%	33%
Benin	0.692	0.800	0.43	45%	1%	65%	33%
Bolivia	0.000	0.640	0.39	43%	0%	100%	0%
Bosnia and Herzegovina	0.596	0.240	0.29	34%	9%	52%	38%
Botswana	1.731	0.180	0.29	41%	22%	29%	49%
Brazil	0.712	0.240	0.29	37%	11%	48%	41%
Bulgaria	0.173	0.090	0.18	23%	14%	63%	22%
Burkina Faso	0.654	0.530	0.38	39%	3%	62%	35%
Cameroon	0.635	0.590	0.39	41%	2%	63%	34%
Chile	1.000	0.090	0.23	34%	35%	25%	39%
China	1.750	0.090	0.26	29%	41%	19%	40%
Colombia	1.135	0.150	0.27	33%	23%	32%	45%
Congo, Dem. Rep.	0.596	0.900	0.45	45%	1%	69%	30%
Congo, Rep.	0.635	0.590	0.39	43%	2%	63%	34%
Costa Rica	0.673	0.210	0.28	37%	12%	47%	40%
Cote d'Ivoire	0.942	0.580	0.39	41%	3%	57%	40%
Djibouti	1.077	0.840	0.44	46%	2%	59%	39%
Dominican Republic	1.692	0.230	0.31	37%	17%	33%	50%
Ecuador	2.596	0.220	0.32	38%	20%	28%	52%
Egypt, Arab Rep.	2.538	0.320	0.35	39%	13%	34%	53%
El Salvador	1.654	0.350	0.35	40%	10%	41%	50%
Ethiopia	0.769	0.230	0.29	30%	12%	46%	42%
Fiji	0.038	0.190	0.24	26%	1%	93%	6%
Gabon	0.827	0.190	0.28	40%	16%	42%	43%
Gambia, The	0.173	0.900	0.44	46%	0%	86%	14%
Georgia	0.077	0.080	0.15	17%	9%	78%	13%
Ghana	3.423	0.310	0.35	36%	15%	31%	54%
Guatemala	1.942	0.270	0.33	36%	15%	34%	51%
Guinea	0.500	0.730	0.42	43%	1%	70%	29%
Guyana	1.077	0.460	0.37	39%	5%	51%	43%
Haiti	0.327	0.900	0.45	46%	1%	78%	22%
Honduras	1.423	0.320	0.33	37%	10%	41%	48%
India	1.077	0.380	0.35	37%	7%	48%	45%
Indonesia	2.077	0.460	0.38	41%	7%	42%	51%

Country	Firing cost (tau)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution To Simulated Output Gap		
					tau	π	complementarity
Iran, Islamic Rep.	1.750	0.060	0.241	32%	53%	14%	34%
Jamaica	1.173	0.060	0.224	27%	49%	17%	34%
Jordan	0.077	0.340	0.312	35%	1%	89%	10%
Kazakhstan	0.173	0.070	0.157	21%	19%	59%	22%
Kenya	0.904	0.270	0.310	32%	10%	46%	44%
Kyrgyz Republic	0.327	0.090	0.193	20%	22%	48%	30%
Latvia	0.327	0.040	0.148	22%	43%	32%	25%
Lebanon	0.327	0.440	0.352	46%	2%	72%	26%
Lesotho	0.846	0.270	0.309	32%	10%	47%	43%
Liberia	1.615	0.900	0.452	46%	2%	55%	43%
Lithuania	0.577	0.050	0.183	29%	46%	25%	30%
Macedonia, FYR	0.500	0.070	0.192	24%	34%	34%	33%
Malawi	1.615	0.820	0.441	45%	2%	54%	44%
Malaysia	1.442	0.130	0.267	38%	29%	26%	45%
Maldives	0.173	0.090	0.176	20%	14%	63%	22%
Mali	0.596	0.790	0.430	44%	1%	68%	31%
Mauritania	0.596	0.570	0.388	41%	2%	64%	33%
Mauritius	0.673	0.100	0.224	30%	28%	34%	38%
Mexico	1.000	0.110	0.244	35%	30%	29%	41%
Micronesia, Fed. Sts.	0.000	0.570	0.379	41%	0%	100%	0%
Moldova	0.712	0.110	0.232	25%	26%	35%	39%
Mongolia	0.173	0.060	0.147	16%	22%	56%	22%
Montenegro	0.750	0.070	0.209	28%	39%	26%	35%
Morocco	1.635	0.080	0.248	27%	44%	18%	39%
Mozambique	2.750	0.470	0.382	39%	8%	39%	53%
Namibia	0.462	0.210	0.273	32%	10%	55%	35%
Nepal	1.731	0.370	0.352	36%	9%	41%	50%
Nicaragua	0.462	0.570	0.387	41%	2%	68%	30%
Niger	0.596	0.900	0.448	45%	1%	69%	30%
Nigeria	0.962	0.290	0.318	33%	10%	46%	44%
Pakistan	1.731	0.130	0.273	29%	31%	24%	46%
Panama	0.846	0.140	0.254	34%	22%	36%	42%
Papua New Guinea	0.750	0.200	0.279	29%	14%	44%	42%
Paraguay	2.173	0.610	0.408	45%	5%	46%	49%
Peru	1.000	0.240	0.301	36%	13%	42%	45%
Philippines	1.750	0.190	0.297	32%	21%	30%	49%
Poland	0.250	0.150	0.228	36%	10%	63%	27%
Romania	0.154	0.040	0.120	16%	30%	51%	20%
Russian Federation	0.327	0.070	0.176	26%	28%	43%	29%
Samoa	0.173	0.260	0.283	31%	3%	77%	20%
Senegal	0.731	0.520	0.379	39%	3%	60%	37%
Serbia	0.481	0.090	0.205	26%	27%	39%	34%
Sierra Leone	3.635	0.900	0.457	46%	3%	47%	50%

Country	Firing cost (tau)	Entry Barrier (π)	Simulated Output Gap*	Percentage Simulated Over Actual Output Gap	Percentage Contribution To Simulated Output Gap: tau	π	complementarity
Solomon Islands	0.846	0.400	0.350	37%	6%	53%	41%
South Africa	0.462	0.090	0.204	26%	26%	40%	34%
Sri Lanka	3.250	0.110	0.285	31%	40%	16%	44%
St. Lucia	1.077	0.150	0.266	34%	23%	33%	45%
Suriname	0.500	0.900	0.447	53%	1%	71%	28%
Swaziland	1.019	0.260	0.309	35%	12%	43%	45%
Syrian Arab Republic	1.538	0.150	0.278	31%	26%	28%	47%
Tajikistan	0.423	0.400	0.342	36%	3%	66%	31%
Tanzania	0.615	0.420	0.352	36%	4%	60%	36%
Thailand	1.038	0.070	0.224	27%	43%	21%	36%
Togo	0.692	0.900	0.448	46%	1%	67%	32%
Tonga	0.000	0.100	0.162	18%	0%	100%	0%
Tunisia	0.327	0.070	0.176	21%	28%	43%	29%
Turkey	1.827	0.130	0.275	38%	31%	23%	46%
Uganda	0.250	0.440	0.350	36%	2%	76%	22%
Ukraine	0.250	0.100	0.193	23%	16%	57%	27%
Uruguay	0.596	0.260	0.299	40%	8%	53%	38%
Uzbekistan	0.423	0.110	0.215	23%	20%	46%	34%
Vanuatu	1.077	0.320	0.330	36%	9%	46%	45%
Venezuela, RB	0.000	0.300	0.292	40%	0%	100%	0%
Vietnam	1.673	0.180	0.292	31%	22%	29%	48%
Yemen, Rep.	0.327	0.890	0.444	47%	1%	78%	22%
Zambia	3.423	0.180	0.310	32%	27%	22%	51%

* Proportional output gap with respect to the U.S. $\left(\frac{\text{Output}_{US}\text{-Output}_i}{\text{Output}_{US}}\right)$ obtained from the model. Output denotes GDP per capita.

Online Appendix

"The Whole is Greater than the Sum of Its Parts: Complementary Reforms to Address Microeconomic Distortions"

This note presents a simplified version with closed-form solution of the Bergoeing, Loayza and Piguillem (BLP) model. There are two main changes with respect to the BLP model: (1) aggregate technology does not grow and (2) the exit rate is independent of productivity. This simpler economy allows to illustrate the timing and the role of each variable in the full version of the model. It also provides intuition and analytical support for the main result of the paper, the complementarity of reforms.

A simpler model

Following the BLP environment, suppose that with probability ρ a firm maintains its current productivity, while with probability $(1-\rho)$ it receives a new draw with density $\phi(\theta)$. Thus, the value of an incumbent firm evolves as

$$q^0(\theta) = e^{\theta}r + \beta[\rho q^0(\theta) + (1-\rho)q^0] \qquad (1)$$

where $q^0 = \int_{-\infty}^{\infty} q^0(\theta)\phi(\theta)\,d\theta$. Hence, $q^0(\theta)$ is the value of firm θ at the beginning of the period and q^0 is the expected value of a new firm; and r is the equilibrium return for the firm.

If a firm has productivity $\theta \geq \overline{\theta},$ it stays in the market; otherwise, it exists. Therefore, the value of an exiter is given by

$$q^0(\theta) = e^{\theta}r + \beta s \qquad (2)$$

Combining both equations, we find

$$q^0 = \int_{\overline{\theta}}^{\infty}\left[\frac{e^{\theta}r + \beta(1-\rho)q^0}{1-\beta\rho}\right]\phi(\theta)\,d\theta + \int_{-\infty}^{\overline{\theta}}[e^{\theta}r + \beta s]\phi(\theta)\,d\theta \qquad (3)$$

If entering the market has a cost $1+\pi$, the equilibrium entry condition implies[1]

$$1 + \pi = \beta q^0 \qquad (4)$$

From equations (4) and (1), we find the equilibrium price of a firm:

$$q^0(\theta) = \begin{cases} \dfrac{e^{\theta}r + (1-\rho)(1+\pi)}{1-\beta\rho}; & if\ \theta \geq \bar{\theta} \\ e^{\theta}r + \beta s; & if\ \theta \leq \bar{\theta} \end{cases}$$

A firm exits if its reselling value is smaller than s. Thus, the marginal exiter must satisfy

$$s = q^1(\bar{\theta}) = \rho q^0(\bar{\theta}) + (1-\rho)q^0$$

Replacing prices and the entry condition in the last equation, we obtain

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[1] This is equivalent to the Euler equation with stochastic discount factor: $1 + \pi = E\,\frac{U_c(t+1)\beta}{U_c(t)}\,q^0_{t+1}$. In steady state the discount factor is constant and equal to β.

$$s = \rho \frac{e^{\bar{\theta}} r + (1-\rho)(1+\pi)}{1-\beta\rho} + \frac{(1-\rho)(1+\pi)}{\beta}$$

which generates the exit threshold

$$e^{\bar{\theta}} = \frac{\beta(1-\beta\rho)s - (1-\rho)(1+\pi)}{\beta\rho r} \qquad (5)$$

From equation (5) we see that reforms are complementary. This complementarity can be direct or indirect, through equilibrium prices. First, keeping *r* fixed, we see that the exit threshold is not only determined by the exit cost, but also by the entry cost. For instance, as $\pi \to \infty$, the exit threshold is completely determined by the entry cost, and changing *s* would have little or no impact on the exit probability of the firms.

The indirect effect comes through *r*, which is the average marginal return on capital. Because the marginal productivity of capital is decreasing in *K*, highly distorted economies would have low *K*, and therefore, high *r*. Moreover, as $r \to \infty$ $(K \to 0)$, the effect on the threshold of changing s vanishes.

Of course, equation (5) depends on the equilibrium value of *r*. To find it, from equation (3) and (4),

$$\frac{(1+\pi)}{\beta} = \int_{\bar{\theta}}^{\infty} \left[\frac{e^{\theta} r + (1-\rho)(1+\pi)}{1-\beta\rho}\right] \phi(\theta)\, d\theta + \int_{-\infty}^{\bar{\theta}} [e^{\theta} r + \beta s]\phi(\theta)\, d\theta$$

Then, solving for *r*,

$$r = \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})] - \beta^2(1-\beta\rho)s\Phi(\bar{\theta})}{\mu - \beta\rho\mu_L}\right] \qquad (6)$$

where $\mu = \int_{-\infty}^{\infty} e^{\theta}\phi(\theta)\, d\theta$ and $\mu_L = \int_{-\infty}^{\bar{\theta}} e^{\theta}\phi(\theta)\, d\theta$.

Since $\phi(\theta) = N(0,1)$, it can be shown that $\mu = e^{\frac{1}{2}}$ and $\mu_L = e^{\frac{1}{2}}\Phi(\bar{\theta}-1)$. Notice that for a sufficiently high $abs(\bar{\theta})$, $\Phi(\bar{\theta}-1) \cong \Phi(\bar{\theta})$, and rewriting equation (6),

$$r \cong \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})]}{e^{\frac{1}{2}}(1-\beta\rho\Phi(\bar{\theta}))} - s\beta^2\right] \qquad (6')$$

which is simpler to interpret than equation (6).

Equations (5) and (6) characterize the equilibrium exit threshold and the average return in the economy. The entry value is determined from the general equilibrium.

As shown in BLP -and abstracting from the labor choice-, in equilibrium it must be true that $r = (1-\alpha)\bar{K}^{-\alpha}$, where $\bar{K}$ is the effective capital stock, or equivalently, the average productivity in the economy. To find $\bar{K}$ requires to characterize the stationary distribution of firms.

Let K_0 be the total number of firms at the beginning of the period, and K_1 be the total number of firms at the end of the period, after the exit decision has been made. Then,

$$k_{t+1}^0(\theta) = \begin{cases} \rho k_t^0(\theta) + (1-\rho)K_t^1\phi(\theta) + I_t\phi(\theta); & if\ \theta \geq \bar{\theta} \\ (1-\rho)K_t^1\phi(\theta) + I_t\phi(\theta); & if\ \theta \leq \bar{\theta} \end{cases}$$

The first term of the first line –incumbents- says that the number of firms in period $t+1$ with productivity θ is equal to the measure of firms with the same productivity in the previous period that do not receive a shock, $\rho k_t^0(\theta)$, plus the incumbents in the last period who receive a shock and draw θ, $(1-\rho)K_t^1\phi(\theta)$, plus the entrants who received a shock θ, $I_t\phi(\theta)$. A similar interpretation follows for the firms that exit in the current period. Therefore, in steady state

$$k^0(\theta) = \begin{cases} \left[K^1 + \dfrac{I}{(1-\rho)}\right]\phi(\theta); & if\ \theta \geq \bar{\theta} \\ [K^1(1-\rho) + I]\phi(\theta); & if\ \theta \leq \bar{\theta} \end{cases}$$

Note that in steady state the upper tail of the size distribution of plants is Lognormal, despite the exit decision. Thus, the total number of firms at the end of the period -adding only future incumbents- is

$$K^1 = \int_{\bar{\theta}}^{\infty} \left[K^1 + \frac{I}{(1-\rho)}\right] \phi(\theta)\, d\theta \Rightarrow K^1 = \frac{I}{(1-\rho)} \frac{[1-\Phi(\bar{\theta})]}{\Phi(\bar{\theta})} \qquad (7)$$

and the distribution of firms at the beginning of the period is given by

$$k^0(\theta) = \begin{cases} \dfrac{I}{(1-\rho)} \dfrac{1}{\Phi(\bar{\theta})}\phi(\theta); & if\ \theta \geq \bar{\theta} \\ \dfrac{I}{\Phi(\bar{\theta})}\phi(\theta); & if\ \theta \leq \bar{\theta} \end{cases}$$

As a result, the total number of firms at the beginning of the period is

$$K^0 = \int_{\bar{\theta}}^{\infty} \frac{1}{\Phi(\bar{\theta})} \frac{I\phi(\theta)}{(1-\rho)} d\theta + \int_{-\infty}^{\bar{\theta}} \frac{1}{\Phi(\bar{\theta})} I\phi(\theta)\, d\theta$$

$$K^0 = I\left[\frac{[1-\Phi(\bar{\theta})]}{\Phi(\bar{\theta})} \frac{1}{(1-\rho)} + 1\right] = I\frac{(1-\rho\Phi(\bar{\theta}))}{(1-\rho)\Phi(\bar{\theta})} \qquad (8)$$

Similarly, the total productivity is

$$\bar{K} = \int_{\bar{\theta}}^{\infty} \frac{1}{\Phi(\bar{\theta})} \frac{I\phi(\theta)e^{\theta}}{(1-\rho)} d\theta + \int_{-\infty}^{\bar{\theta}} \frac{1}{\Phi(\bar{\theta})} I\phi(\theta)e^{\theta}\, d\theta$$
$$\bar{K} = \frac{I}{(1-\rho)\Phi(\bar{\theta})}[\mu - \rho\mu_L] \qquad (9)$$

Therefore, the equilibrium is fully characterized by the variables $\{\bar{\theta}, r, I, \bar{K}\}$ solving

$$e^{\bar{\theta}} = \frac{\beta(1-\beta\rho)s - (1-\rho)(1+\pi)}{\beta\rho r}$$

$$r = \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})] - \beta^2(1-\beta\rho)s\Phi(\bar{\theta})}{\mu - \beta\rho\mu_L}\right]$$

$$r = (1-\alpha)\bar{K}^{-\alpha}$$

$$\bar{K} = \frac{I[\mu - \rho\mu_L]}{(1-\rho)\Phi(\bar{\theta})}$$

Finally, note that in this version of the BLP model without technology adoption, the average level of productivity is,

$$\frac{\bar{K}}{K^0} = \frac{[\mu - \rho\mu_L]}{(1-\rho\Phi(\bar{\theta}))}$$

which is independent of investment and entry. This creates unusual comparative statics. For instance, reducing the threshold increases the total production in the economy. One way to deal with this problem in this example is to assume a reduced form externality, like

$$\bar{K} = \frac{I[\mu - \rho\mu_L]e^{aI}}{(1-\rho)\Phi(\bar{\theta})}$$

For some $a > 0$, this would make the simpler model similar to the main model in the paper. Using equation (6'), with the definition of r and the last equation,

$$(1-\alpha)\bar{K}^{-\alpha} \cong \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})]}{e^{\frac{1}{2}}(1-\beta\rho\Phi(\bar{\theta}))} - s\beta^2\right]$$

$$\bar{K} \cong \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})]}{e^{\frac{1}{2}}\left(1-\beta\rho\Phi(\bar{\theta})\right)} - s\beta^2\right]^{-\frac{1}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}}$$

$$\frac{Ie^{\frac{1}{2}}(1-\rho\Phi(\bar{\theta}))e^{aI}}{(1-\rho)\Phi(\bar{\theta})} \cong \left[\frac{(1+\pi)[1-\beta+\beta(1-\rho)\Phi(\bar{\theta})]}{e^{\frac{1}{2}}\left(1-\beta\rho\Phi(\bar{\theta})\right)} - s\beta^2\right]^{-\frac{1}{\alpha}} (1-\alpha)^{\frac{1}{\alpha}}$$

This equation solves for the equilibrium value of I.

Again, one can analyze the complementary with this equation: if s is sufficiently low, so that $\bar{\theta} \to -\infty$, and therefore $\Phi(\bar{\theta}) \to 0$, the impact of π on I is null. That is, the exit barrier nullifies the entry reforms.

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