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The Aggregate Impact of Micro Distortions: Complementarities Matter

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The aggregate impact of micro distortions: complementarities matter*

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We explore how developmental and regulatory impediments to resource reallocation limit the ability of developing countries to adopt technologies: an efficient economy quickly innovates; but when the economy is unable to fully use resources liberated by closing firms, or when policy distortions deter firm dynamics, then technological adoption becomes sluggish, and growth is reduced. Our theory accounts for 75% of the income (GNI) gap between Latin America and the U.S. Half of this simulated gap is explained by the barriers individually, the other half by their complementarity. Thus, the benefits from market reforms are largely diminished if distortions, developmental as well as regulatory, are not uniformly eliminated.

***JEL** classification:* O1, O4
Key Words: general equilibrium, firm dynamics, technological adoption, developmental and regulatory barriers.

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1. Introduction

There is a large disparity among countries regarding the rate of adoption of even inexpensive technologies. To understand why, we focus on impediments to firm dynamics. When resource reallocation and firm renewal are not restrained, domestic enterprises are able to quickly incorporate the advances of a rising technological frontier. In contrast, when the firms' natural dynamics are obstructed (for instance with red tape or exit costs) a countries' ability to adopt new technologies can be severely handicapped, and growth is reduced. We show that a sizable fraction of the gap in income per capita between Latin America and the U.S. – around 75% - is accounted for by these obstacles. We also show that not just removing the barriers, but removing them simultaneously is critical: half of the gap generated by our model economy results from adding each barrier individually, the other half from their complementarity.

Starting with the work of Hopenhayn and Rogerson (1993), Caballero and Hammour (1994), and Davis, Haltiwanger, and Schuh (1996), a large body of literature shows the key role of firm dynamics in increasing microeconomic productivity and, consequently, aggregate growth. The entry and exit of firms, involving the reallocation of resources from less to more efficient economic units, explain a substantial share of productivity improvements in the economy. Resource reallocation, however, implies costly adjustment: it requires the adoption of new technologies and the assimilation of production inputs by expanding firms, and the shredding of labor and capital by declining firms. Without this costly process, economies would be unable to both reap the benefits of an expanding production possibilities frontier --the source of long-run growth - and absorb and accommodate negative shocks --the antidote to protracted recessions.

Some of the impediments to resource reallocation and 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, however, 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. These distortions, and their implied misallocation of resources, have been blamed for the observed differences in growth experiences across countries. In their influential book, Parente and Prescott (2000) argue 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. They ascribe them to monopoly-like denials of access to the best technology. 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) conclude 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. Also focusing on industrial countries, Gust and Marquez (2004) present empirical evidence that economies with highly regulated labor and product markets face greater difficulty in incorporating information technologies and suffer from lower productivity growth.

We analyze the process of technological innovation from the perspective of developing countries, that is, as an adoption process. Moreover, in contrast to the papers focused on rich nations, we not only take into account the policy-induced regulatory obstacles to firm dynamics but also the shortcomings inherent to underdevelopment, such as poor education and faulty governance. We also analyze how these types of impediments interact with each other to affect firm dynamics and, consequently, technological adoption.[1] As we explicitly model this connection between micro distortions and technology adoption, we provide a theory of endogenous productivity.[2] In this paper, firms can only innovate by acquiring new machines with "state of the art" technology. Thus, distortions that affect the rate at which the machinery is replaced affect not only the capital output ratio, but the productivity level as well.

We first present some motivating evidence on the importance of developmental and regulatory characteristics for the purpose of technological innovation. Using the availability of personal computers and incidence of internet users as proxies of technological progress, we study how they are related to governance, schooling and regulatory freedom in a large cross-section of countries. We find that these characteristics not only exert a positive independent effect on technological innovation but also complement each other in this regard.

To understand these relationships, we then construct a stochastic general equilibrium model with heterogeneous firms. Firms differ with respect to their level of productivity, which is determined by their initial technology and history of idiosyncratic shocks. Old firms tend to become less productive than young firms with more advanced technologies, and eventually leave the market. In doing so, they release resources that are then used to form new firms, which acquire the leading-edge technology and enter the market. The technological frontier expands according to a stochastic and exogenous process. This intends to capture the way developing countries relate to technological advances, that is, as takers and users rather than developers of new technologies.

Developmental barriers --such as poor governance and lack of education-- are modeled as a parameter that affects the adjustment cost of investment: the salvage value of capital. The intuition for this assumption is that in conditions of underdevelopment,

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[1] Jovanovic (2009) provides an alternative explanation for the lack of technological innovation among developing countries. He argues that licensing costs keep technologies away from developing countries since their productivity is too low to warrant paying the fee.

[2] Although this paper is specifically concerned with the issue of technological innovation, the mechanism that we study (i.e., firm renewal to take advantage of exogenous shocks) can be applied to other externally generated events. One of them is related to trade prices. If world conditions induce a terms-of-trade shock, only countries that can shift resources towards the most profitable sectors will be able to take full advantage of the shock. The current world economic crisis is another example. It has created an increase in the U.S. demand for certain products --such as low-end retail merchandising or fuel-efficient automobiles-- that can benefit the most dynamic developing countries, even in the middle of an international crisis.

the value of capital depends on the informal knowledge and institutional networks associated to a particular activity. In this case, capital cannot be easily transformed to serve as production factor elsewhere. As countries develop, however, the value of capital becomes more related to broadly applicable human capital (e.g., engineers that can work with a large variety of machines) and formal institutions (e.g., contracts that are enforced by the judicial system irrespective of economic activity, production sector, or geographic location). With higher development, capital can be retooled and reconverted, thus facilitating the process of technological adoption. Regulatory barriers are, in turn, modeled as entry taxes (representing red tape and registration fees) or exit taxes (such us bankruptcy and closing costs).

According to this theory, differences in income levels are accounted for by differences in the speed of technological adoption. Since world knowledge expands continuously, economies that permanently keep obstacles to innovation lag behind the leading-edge technology, and thus, the leaders' income per capita. Using this framework, we calibrated the model economy to the U.S. and the median Latin American country --our representative developing economy. The empirical counterpart of the chosen distortions is taken from the World Bank Doing Business database.

Then, we conduct simulation exercises to analyze the independent impact of each developmental and regulatory barrier and the complementarities between them. Consistent with the data, we observe a slow adoption of new technologies by developing economies and a **complementarity** between developmental barriers and policy distortions. That is, the effect of regulatory freedom on technological innovation – and on the level of aggregate productivity – is larger the higher the level of economic development, and vice versa. Our theory accounts for 75% of the income gap between Latin America and the U.S. Half of this gap is explained by the barriers individually, the other half by their **complementarity**. We also show that our theory generates dynamics of adoption that are consistent with the data.[3]

In short, we provide a theory of development where differences in income levels are accounted for by differences in the speed of technological adoption. Since world knowledge expands continuously, economies that keep obstacles to innovation permanently lag the leading-edge technology, and thus, the leaders' income per capita. At the end, even though all economies are adopting all innovations, poor economies are

[3] Samaniego (2006) also studies technological adoption within general equilibrium. However, that paper focuses exclusively on policy distortions: subsidies that enable plants to survive longer allow more of them to enter the stage of their life at which renewing their technology becomes optimal. Nonetheless, the economy spends a lot of resources on keeping alive plants that would otherwise have shut down, and this results in a reduction in both output and employment on the aggregate. Restuccia and Rogerson (2008) use a similar model to account for cross-country differences in income per capita. They show that policies which create heterogeneity in the prices faced by individual producers can lead to sizeable decreases in output and measured TFP in the range of 30 to 50 percent. Hsieh and Klenow (2009), using micro data on manufacturing establishments, calculate 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.

always behind.

We conclude with a policy implication: Reforms must be undertaken jointly in a comprehensive way. Market oriented reforms have been undertaken in developing countries during the last two decades. Frequently, however, reforms are implemented without a comprehensive plan, so when one reform is in place, other obstacles to reallocation remain. Our theory suggests that the benefits from liberalizing international trade or privatizing publicly owned firms, for instance, are largely reduced when distortions are not uniformly eliminated.

The paper is organized as follows. The following section provides some motivating facts. Section 3 presents a model of entry and exit. Section 4 discusses the calibration. Section 5 analyzes the steady state. Section 6 delivers the main results of the paper and the dynamics of the economy. Finally, Section 7 concludes.

2. Some facts

The differences across countries regarding technological adoption are quite large. Studying 115 technologies in 150 countries, Comin, Hobijn, and Rovito (2006) conclude that the average dispersion of technology across countries is 3 times larger than the dispersion of income per capita, and for 68 percent of the technologies their cross-country dispersion is larger than that 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: a little over two decades ago, they were practically nonexistent almost everywhere; since then, they have been adopted at different rates throughout the world. This may allow us to characterize the effect of certain initial conditions on recent adoption levels of these technologies.[4]

Before proceeding to the econometric exercise, let's consider some stylized facts about these technologies. To maximize data quality and coverage across countries, we work with two indicators: the number of personal computers per 1,000 people as proxy for technological progress in production and management processes; and the number of internet users per 1,000 people as proxy for the advance in telecommunications and information gathering. Figure 1 presents some regional comparisons on these technologies, both in levels as of 2003-04 and in changes between 2003-04 and 1994-96.

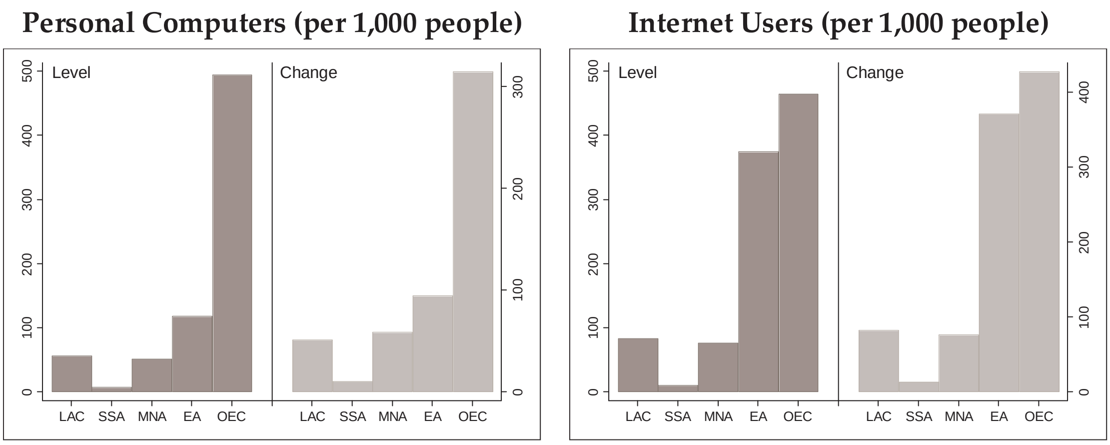
Since these technologies are rather recent, the comparisons based on levels and changes are quite similar. The OECD far surpasses any developing region. The typical OECD country has 5 times more personal computers per capita than the typical East Asian developing country, 10 times more than the typical Latin American or Middle Eastern countries, and about 50 times more than the typical Sub-Saharan African country. Regarding internet usage, the gaps are smaller but still considerable. The

[4] As mentioned above, the empirical exercise is reported only as motivation and suggestion of the type of results the model should be directed at.

typical OECD country leads the typical East Asian developing country by 25%, while the other regions --Latin America, the Middle East, and specially Sub-Saharan Africa-- lag much farther behind.

These regional differences are clearly related to income levels, providing some evidence on the importance of the developmental barriers mentioned above. What about regulatory barriers? Figure 2 shows some evidence that they are also potentially important. Using the Fraser index of business regulatory freedom, we divide countries into three groups. For each of them, we plot the group average of both personal computers and internet users per population for each year in the period 1990-2004. Countries in the top quartile of regulatory freedom (countries with lower regulations) have much higher levels and speeds of adoption of both technology indicators. Countries in the middle (inter-quartile) range of regulatory freedom also experience an increase over time but, having started their rise much later, show levels of technology adoption in the mid 2000s that are between one-third and one-half of those in the top quartile. Finally, countries in the bottom quartile of regulatory freedom start the adoption process much later and slowly than the others, resulting in enormous technology gaps with respect to the leaders.

Figure 1. Technological Innovation per World Region



Notes: 1. LAC: Latin America and the Caribbean; SSA: Sub-Saharan Africa; MNA: Middle East and North Africa; EA: ASEAN+2 (South Korea and China) excluding LICs; OEC: OECD. 2. Median value of each country group. 3. Level indicates an average of 2003-2004 by country, and change means the difference between the periods 2003-2004 and 1994-1996. 4. Data on Personal Computers and Internet Users are from World Development Indicators.

The evidence presented above is suggestive that both developmental and regulatory barriers play a role in explaining technological differences across countries.

For more careful empirical support, we now turn to cross-country regression analysis. This will allow us to ascertain whether each proposed determinant of technological adoption exerts a statistically significant impact, even after controlling for the effects of the other determinants. Moreover, this analysis will help us understand to what extent the proposed determinants complement each other regarding their effect on technological adoption.

Table 1 presents information and results of the cross-country regression analysis. The dependent variables are the two indicators of technological innovation, that is, personal computers and internet users, both normalized by population. The explanatory variables are intended to capture the most relevant developmental and regulatory characteristics --the first represented by governance and schooling, and the second one, by business regulatory freedom.[5] Specifically, for the quality of public institutions and governance, we use an index based on International Country Risk Guide indicators on the rule of law, bureaucratic quality, and absence of official corruption. For education and human capital, we use the Barro and Lee (2001) measure of average schooling years of the adult population. For regulatory stance, we use the Fraser Institute Index of Regulatory Freedom. Appendix 1 provides additional information on definitions and sources of the three explanatory variables.

The explanatory variables are all measured at the period 1994-96, while the dependent variables are measured at 2003-04. We lag the explanatory variables sufficiently to be able to consider them as pre-determined while still connected to the dependent variables. The resulting samples consist of 83 and 90 countries for the regressions on personal computers and internet users, respectively.

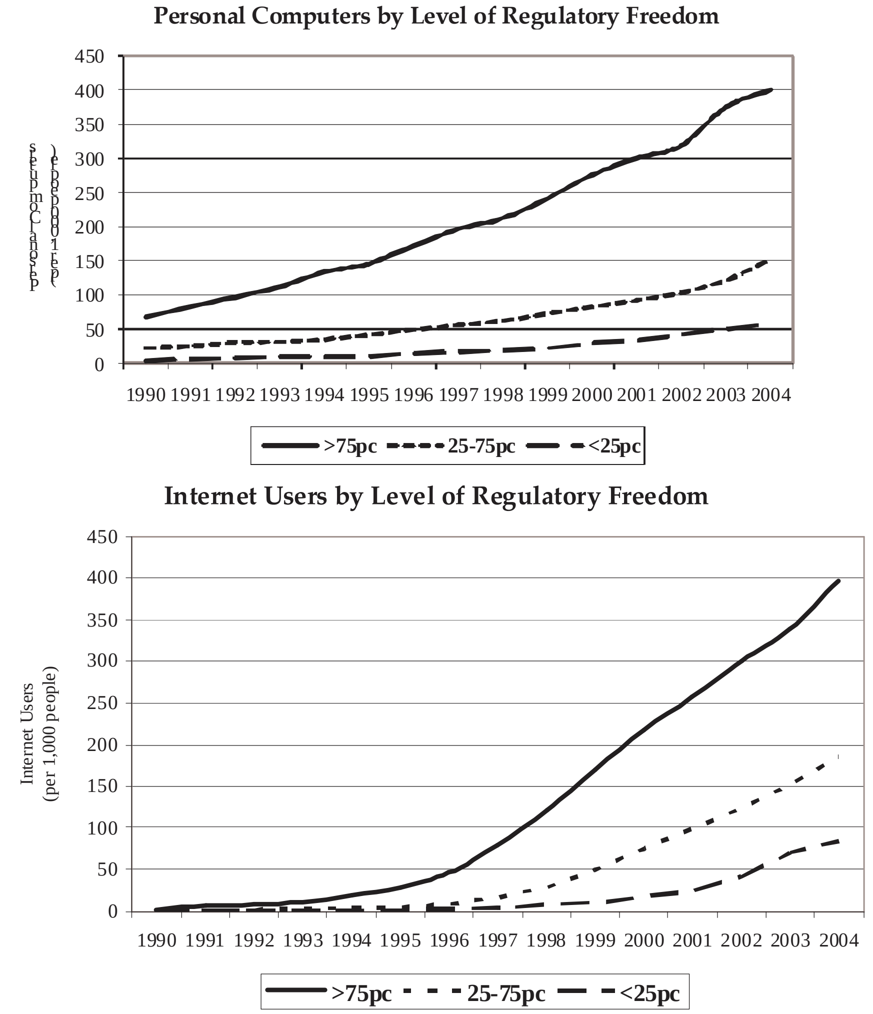
For each dependent variable, we run three analogous regressions. The first estimates only linear effects, while the second and third allow for multiplicative interactions. The linear regression results show that *all* explanatory variables carry positive and statistically significant coefficients, indicating that each of them independently is a relevant determinant of technological innovation. More regulatory freedom, better governance, and higher schooling all lead to faster technological adoption. Moreover, the results suggest that *both* developmental and regulatory barriers should be considered in any attempt to explain cross-country differences of technological innovation and, in particular, the backwardness suffered by some developing countries.

Since these barriers and income per capita are highly correlated and interact with each other, our estimations may be biased. For two reasons, however, we do not include income per capita as an explanatory variable. First, as explained below, neither the significance, nor the signs of the estimated parameters do change when the regressions are corrected by income per capita. Second, we consider the entry and exit barriers as the only exogenous variables causing income per capita and technology adoption. Finally,

[5] We make this selection based on the received literature on growth and technological innovation --see De Soto (1989) and Parente and Prescott (2000) on regulatory freedom; Olson (1982) and Acemoglu, Johnson, and Robinson (2005) on institutions and governance; and Lucas (1988) and Glaeser et al. (2004) on human capital and schooling.

since we focus on the steady state effect of barriers, a reduced form estimation of the model should include barriers as the only explanatory variable.[6]

Figure 2. Technological Innovation and Regulatory Freedom



Notes: 1. Lines show average per group (top quarter, inter-quartile range, bottom quarter) according to Regulatory Freedom as of mid 90s. 2. Data on Personal Computers and Internet Users are from World Development Indicators. Data on Regulatory Freedom are from the Fraser Institute.

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[6] In exercises not reported here, we included per capita GDP in the mid-1990s as an additional explanatory variable. In the regression featuring only linear effects, the variables on regulatory freedom, governance, and schooling retained their sign and significance. In the regressions featuring the multiplicative term, the coefficients on the interaction between regulatory freedom and each of the developmental indicators remained positive and significant. However, given the very high correlation between per capita GDP and the developmental indicators of governance and human capital, the inclusion of per capita GDP obscured the interpretation of those indicators and we decided to exclude it from the basic regressions.

Table 1. Technological innovation

Method of estimation: Ordinary Least Squares with Robust Standard Errors

	Personal Computers (per 1,000 people)			Internet Users (per 1,000 people)		
Regulatory Freedom	25.48*	-132.01**	-67.26**	26.44**	-77.05**	-12.42
(index of Credit, Labor and Business Regulation, by The Fraser Institute: higher, less regulated; country average)	[1.97]	[3.09]	[2.25]	[2.06]	[2.66]	[0.51]
Governance	110.07**	-138.22*	102.11**	83.02**	-73.24	81.66**
(simple average of ICRG Law and Order, Bureaucracy Quality and Corruption indices: higher, better governance; country average)	[7.39]	[1.74]	[6.86]	[5.04]	[1.59]	[5.02]
Schooling	28.96**	33.94**	-41.49	26.08**	28.53**	-4.41
(average schooling years in the population aged 15 and over, from Barro and Lee (2001); country average)	[3.66]	[4.70]	[1.42]	[3.07]	[3.61]	[0.21]
Regulatory Freedom * Governance		39.85**			26.20**	
		[3.27]			[3.44]	
Regulatory Freedom * Schooling			12.67**			5.41*
			[2.56]			[1.68]
No. of observations	83	83	83	90	90	90
R-squared	0.78	0.82	0.81	0.75	0.77	0.75

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. Dependent variables are measured as average of the period 2003-04. Explanatory variables are measured as of mid 1990s. 3. Data on dependent variables are from World Development Indicators and on explanatory variables, as indicated below each variable.

To assess both the direct effects of developmental and regulatory characteristics and whether they complement each other, we now consider the regressions where the regulatory freedom variable is interacted with, in turn, the governance and schooling variables. These regressions show a clear and robust pattern: the coefficients on all the multiplicative interactions for both dependent variables are positive and statistically significant. That is, governance and schooling complement regulatory freedom, compounding each other's effect on the availability of personal computers and internet usage.

We can use the estimated coefficients to evaluate the effect of an increase in regulatory freedom on technological innovation. For this purpose, we need to consider the coefficients on both the interaction term and regulatory freedom itself.[7] Given that the total impact depends on the values of the variables with which regulatory freedom is interacted, it is not informative to provide a single summary measure of the effect. Instead, we show how this effect varies with governance and schooling.

Figure 3 presents the total effect on both personal computers and internet users of a one-standard-deviation change in the regulatory freedom index as a function of the values of either governance or schooling. In addition to the point estimates, the figure shows the corresponding 90% confidence bands (constructed from the estimated variance-covariance matrix of the corresponding parameters). It shows that if governance and schooling are very low, an increase in regulatory freedom may not lead to higher levels of technological innovation. However, as countries advance in governance, institutions, schooling and human capital, they are more likely to take advantage of larger regulatory freedom to speed up the process of technological adoption.[8] What explains this pattern of complementarity between regulatory and developmental characteristics to achieve technological innovation? The mechanism we propose in this paper is based on the incentives and costs of firm renewal. We develop this mechanism in our model, to which we turn now.

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[7] The regression with interaction terms implies the following formula for the point estimate of the total effect of a change of regulatory freedom on either proxy of technological innovation,

$$\Delta Tech = (\beta_{REGFREE} + \beta_{INT}\, DEV)\, \Delta REGFREE$$

Where *Tech* represents either personal computers or internet users, *DEV* represents either governance or schooling, *REGFREE* indicates regulatory freedom, the symbol Δ denotes change, and the parameters $\beta_{REGFREE}$ and β_{INT} are the estimated regression coefficients on, respectively, regulatory freedom and the interaction between regulatory freedom and governance or schooling. Note that $\Delta REGFREE$ is an arbitrary constant, which we set to equal one sample standard deviation of the regulatory freedom index, and *DEV* corresponds to any point in the set of values given by the sample range of either governance or schooling. $\Delta REGFREE$ and *DEV* can thus be treated as constants. Then, variance of the point estimates (of the effect of a given change of regulatory freedom on personal computers or internet users) can be obtained as follows,

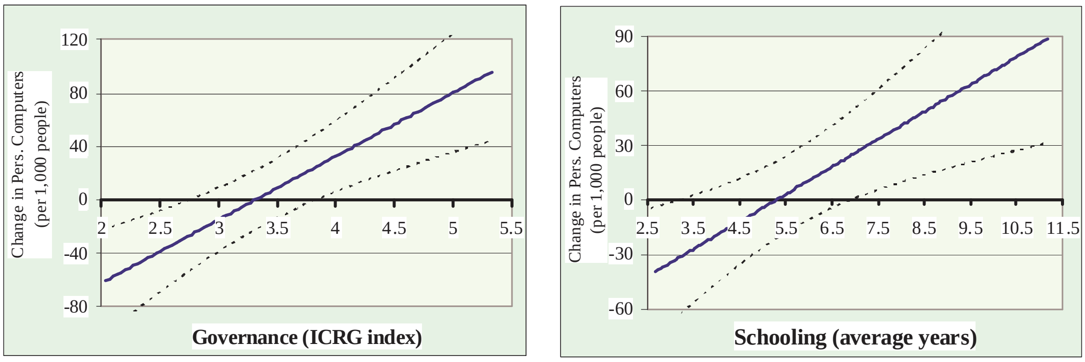
$$\text{Var}[\Delta Tech] = \{\text{Var}(\beta_{REGFREE}) + DEV^2\, \text{Var}(\beta_{INT}) + 2\, DEV\, \text{Cov}(\beta_{REGFREE}, \beta_{INT})\}\, \{\Delta REGFREE\}^2$$

Using this variance, we construct the confidence intervals shown in Figure 3.

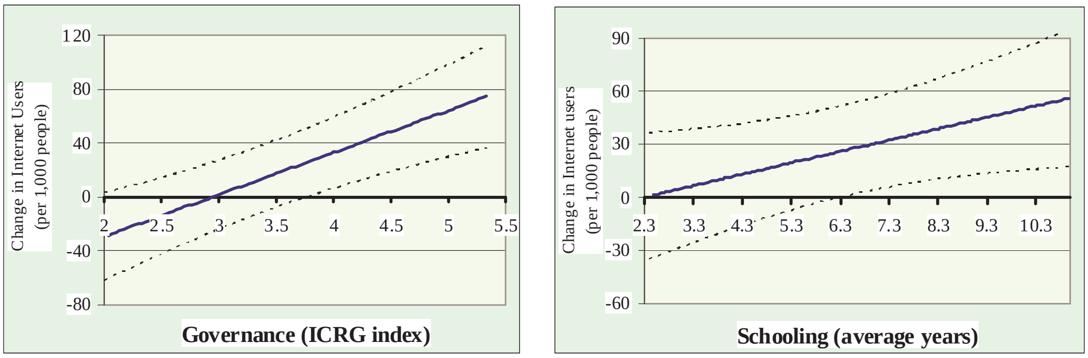
[8] The panels of Figure 3 show that for very low levels of governance or schooling, the effect of an increase of regulatory freedom on computer and internet adoption seem to be negative. In additional exercises, we explored whether this negative result may be due to a non-linearity in the interaction. Indeed, when we interacted regulatory freedom with not only the linear term but also the square term of the corresponding developmental indicator, we found an upward-concave shape for the effect of regulatory freedom on technological adoption. For very low levels of governance or schooling the slope of the effect of regulatory freedom on technological adoption was flat and close to zero; as the levels of governance and schooling increased, the slope of this effect increased markedly. For simplicity we only present here the simple linear interaction specification.

Figure 3: Innovation Effect of an Increase in Regulatory Freedom as Function of Governance and Schooling

Personal Computers



Internet Users



Notes: 1. The solid lines show the effect of a one-standard-deviation increase in the index of regulatory freedom on personal computers and internet users, respectively; 2. The x axis represents the .05-.95 percentile range of, respectively, governance and schooling in the sample; 3. Dotted lines are 90% confidence bands.

3. A model of plant selection

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). There exists a distribution of plants characterized by different levels of productivity. In each period, plant managers decide whether to exit or stay in business. If a plant stays, the manager must decide how much labor to hire. If the plant exits, it is worth a sell-off value. Every period the incumbents receive an idiosyncratic productivity shock. In addition, new plants enter every period. The initial technology level of a newcomer is random, although increasing in the leading edge production technology. New plants are produced by a "construction" firm with a constant return to scale technology.

In this context, the economy is characterized by an ongoing process of plant entry and exit, and the corresponding creation and destruction. Plants exit if economic prospects loom negative. They may also exit if their current technology becomes obsolete and, by selling their capital off, owners gain access to the leading-edge technology –Schumpeter's process of creative destruction. However, exiting is costly as capital loses some of its value in the process. These investment irreversibilities, as modeled by Caballero and Engel (1999), combined with idiosyncratic uncertainty, generate an equilibrium solution where plant owners rationally delay their exit decisions.

We allow for exogenously imposed rigidities. In particular, we study the effect of policies that alter firms' decisions to leave or stay in the market.. Governments are willing to impose such policies to reduce the volatility and short run social and political costs associated to the entry – exit process or simply to collect revenues. By altering this natural process of firm dynamics, the government also reduces the loss of resources due to capital irreversibility. As mentioned above, we interpret the loss due to capital irreversibility as indicative of the economy's level of development. Thus, micro dynamics are affected both by government and developmental barriers. The larger these are, the lower the level of technology adoption that developing economies engage in, and the larger their income gap with rich economies. Our simulation results are consistent with this fact: as the leading edge technology expands, barriers to the extensive margins dampen the reallocation process reducing short-run output losses at the cost of lower adoption, lower productivity gains, and a lower output trend.

To relate our model to the existing micro dynamics literature, we refer to production units as "plants". However, we do not provide a theory of the firm or the plant. In our model the size of the firm as a collection of production units is indeterminate, and, therefore, the modeled entry-exit dynamics can occur either within or across *actual* firms or plants. Nevertheless, to the extent that a firm or plant activities tend to consist of interrelated production units (or investment projects), we expect that there is a considerable correlation between production dynamics in the model and actual plant dynamics.

The gap between the definition of production units in the model and in the data implies that our model abstracts from reality in other dimensions that are also relevant for the specification of parameters, as well as for the interpretation of our results. On the one hand, only new plants invest. In the data investment is carried out by both new and old plants. On the other hand, plants may adopt new technologies without actually closing. Thus, we conjecture that the magnitude of entry and exit implicit in the model is an upper bound of those in reality.[9] In what follows we describe our model in detail.

The model economy: The economy is populated by a continuum of heterogeneous plants. A plant needs labor (n) and capital (k) for production of the unique good, which can be used for consumption or investment. This production good is the *numeraire*.

[9] In simulations available upon request, we find that in an economy with technological adoption by incumbents, the results are qualitatively unchanged.

Each plant's technology is given by

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

where A is aggregate productivity common to all establishments (a scale factor), and θ_t is the idiosyncratic productivity at period *t*. The notation $k_t(\theta_t)$ reflects the fact that the technology θ_t is embodied in the plant.

Since technologies are characterized by constant returns to scale, we can restrict the size of all plants to be equal to one unit of capital. Thus, capital goods are identified with plants so that investing one unit of the aggregate good yields a unit mass of plants. Then, from now on $k_t(\theta_t)$ will represent the density of plants with embodied technology θ_t as well.

The aggregate production function of this model economy is:

$$Y_t = AN_t^{\alpha}\left[\int_{-\infty}^{\infty} e^{\theta_t}k_t(\theta_t)d\theta_t\right]^{1-\alpha} = AN_t^{\alpha}\overline{K}_t^{1-\alpha} \tag{2}$$

where $\overline{K}_t = \int_{-\infty}^{\infty} e^{\theta_t}k_t(\theta_t)d\theta_t$ is the aggregate effective capital stock.

Capital embodying relatively low level of technology is scrapped as its productivity lags behind that of the leading edge technology. When a plant is retired, a unit of capital that is scrapped has salvage value $s < 1$. The total amount of salvaged capital in period *t* is then

$$S_t = (1-\delta)s\int_{-\infty}^{\overline{\theta}_t} k_t(\theta_t)d\theta_t \tag{3}$$

where $\overline{\theta}_t$ is the endogenous cut-off level of productivity that determines the exit decision of plants and δ is the capital's depreciation rate .

Units of the production goods not consumed -- which are made up of investment and part of last period's scrapped capital --, are transformed into new units of capital embodied with the leading edge technology. That is, the initial productivity level of a plant born in period *t* is a random variable with a normal distribution $\theta_{t+1} \sim \mathrm{N}\left(z_t, \sigma^2\right)$, where z_t represents the level of leading edge technology. This stochastic variable follows a random walk with a positive drift μ_z according to

$$z_{t+1} = \mu_z + z_t + \varepsilon_{t+1}^z, \quad \varepsilon_{t+1}^z \sim \mathrm{N}\left(0, \sigma_z^2\right). \tag{4}$$

This drift is the only source of long-run aggregate growth in our economy.

Capital that is not scrapped receives an idiosyncratic shock to its productivity level before next period production process starts, according to

$$\theta_{t+1} = \theta_t + \varepsilon_{t+1}^{\theta}, \qquad \varepsilon_{t+1}^{\theta} \sim \mathrm{N}\left(0, \sigma_{\theta}^2\right) \tag{5}$$

This idiosyncratic shock has zero mean and thus, it does not affect the economy´s long-run growth rate. The random walk property of the stochastic process ensures that the differences in average productivity across units of capital persist over time. Thus, at any t, the units of capital with more advanced technology have a lower probability of shutting down.

Summarizing, there are two sources of uncertainty: first, an idiosyncratic productivity shock, ε_t^{θ} , that determines the plant level decisions of incumbents. This shock does not alter the aggregate equilibrium allocation. Second, a leading edge idiosyncratic productivity shock, ε_t^{z} , that governs the economy's aggregate growth. Notice that plants, as they decide to stay or leave, choose between the following distributions:

$$\theta_{t+1} \sim \mathrm{N}\left(\theta_{\mathrm{t}}, \sigma_{\theta}^2\right) \tag{6}$$

$$\theta_{t+1} \sim \mathrm{N}\left(\mathrm{z}_{\mathrm{t}}, \sigma^2\right) \tag{7}$$

Plants last only one period. At the beginning of the period, firms decide production and hiring. The wage rate in period t is ω_t , and the beginning and end of period prices of a plant with productivity θ_t are $q_t^0(\theta_{\mathrm{t}})$ and $q_t^1(\theta_{\mathrm{t}})$, respectively. Within this setting, given the number of units of capital with productivity θ_t, $k_t(\theta_{\mathrm{t}})$, the employment assigned to each plant is given by

$$n_t(\theta_t) = N_t^{\alpha} e^{\theta_t} / \overline{K}_t \tag{8}$$

After production, firms decide which plants should be scrapped and which ones should be maintained in business. Firms sell their production units and salvaged capital to the consumer and to a construction firm that produces capital embodying the leading edge technology. The construction firm, which buys I_t^c units of the aggregate good from the producer, incorporates the leading edge technology at zero cost, and then sells it to consumers at the end of the period at a price per unit q_t^{1i} . Profit maximization requires the price of the construction project to be equal to the cost of inputs. That is,

$$q_t^{1i} = 1 \,. \tag{9}$$

The distribution of capital evolves according to the law of motion

$$k_{t+1}^{0}(\theta_{t+1}) = \int_{-\infty}^{\infty} \frac{1}{\sigma_\theta} \phi\left(\frac{\theta_{t+1} - \theta_t}{\sigma_\theta}\right) k_t^1(\theta_t) d\theta_t + \phi\left(\frac{\theta_{t+1} - z_t}{\sigma}\right) I_t^c, \quad \textit{for all } \theta_{t+1} \tag{10}$$

Since asset prices equal discounted expected dividend streams, increases in the level of productivity raise these prices; and since the scrap value of a plant is independent of its productivity, only plants with productivity level below the threshold $\overline{\theta_t}$ exit the market. Thus, the marginal plant, that is, the one with productivity level $\overline{\theta_t}$, must have a market value given by the scrap value. The following equation states this condition.

$$s = q_t^1(\overline{\theta_t}) \tag{12}$$

Finally, the purchasing price of a unit of capital is determined not only by its marginal productivity, less any operating costs, but also by the price at which the capital left after depreciation may be sold at the end of the period. Thus, for each θ_t, the purchase and sale decisions of capital units must be characterized by the zero profit condition:

$$q_t^0(\theta_t) = (1-\alpha)\left(\frac{\overline{K}_t}{N_t}\right)^{-\alpha} e^{\theta_t} - \pi_t + (1-\delta)\left[1\{\theta_t < \overline{\theta}_t\}s + 1\{\theta_t \geq \overline{\theta}_t\}q_t^1(\theta_t)\right] \tag{13}$$

where $1\{\cdot\}$ is an indicator function that equals one if its argument is true and zero otherwise. This condition restricts the beginning of period price to be the return from using the capital plus the price at which it can be sold at the end of the period. The parameter π deserves further explanation. This parameter is a cost (fee and/or tax) per plant that the firm has to pay to be able to operate. Notice that π is independent of the productivity of the particular plant. With this we try to capture the impact of some governmental costly restrictions such as legal fees, government permits, required process, etc, whose cost is mostly independent either of the size of the plant or its sales.

In addition we consider a tax on investment, τ_t and a tax on labor income, τ_t^{ϖ} . Since in this economy all the investment is carried on by the households, the tax τ_t appears in the consumer's problem. All taxes and fees follow an AR(1) process with parameters ρ^i i=τ,π,τ^ω for the autocorrelation coefficient and σ_i^2 i=τ,π,τ^ω for the residual variance. Thus, we consider policies that alter both the intensive (a payroll tax) and the extensive (entry and exit) margins. The government′ s budget constraint is guaranteed to be satisfied by adding a lump-sum transfer to consumers.

The remainder of the model is standard. There is a continuum of identical infinitely lived consumers who own labor and equity. Their preferences are given by

$$E_0\left[\sum_{t=0}^{\infty}\beta^t\left(\log(c_t)+\kappa(1-n_t)\right)\right] \tag{14}$$

where c_t and $1-n_t$ are consumption and leisure, respectively, and β ∈ (0,1) is the subjective time discount factor. Every period, consumers have a time endowment equal to 1. Notice that we assume that the utility function is linear in leisure. [10] Following Hansen (1985) and Rogerson (1988), this can be interpreted as an environment in which consumers, with standard utility functions, can work only a fixed number of hours or none at all, and they can trade employment lotteries. Thus, n_t is interpreted as the fraction of the population that works.

Definition of the equilibrium: A *Competitive Equilibrium* in this economy is a set of decision rules $\{I_t, c_t, \{n_t(\theta_t), k_t(\theta_t), y_t(\theta_t)\}_{\forall\theta_t}\}_{t=0}^{\infty}$, stochastic variables $\{c_t, I_t, Y_t, \overline{K}_t, N_t, S_t\}_{t=0}^{\infty}$, contingent prices $\{\omega_t, q_t^1, q_t^0, q_t^{1i}\}_{t=0}^{\infty}$, and a vector $\{\overline{\theta}_t\}_{t=0}^{\infty}$ such that, given contingent prices, the transfer T_t, and production and government stochastic processes $\{z_t, \theta_t, \tau_t, \pi_t, \tau_t^{\omega}\}_{t=0}^{\infty}$, at each period *t*:

1) Given the initial holding of capital, the representative consumer maximizes utility subject the her budget constraint and the law of accumulation of capital:

$$E_0\left[\sum_{t=0}^{\infty}\beta^t\left(\log(c_t)+\kappa(1-n_t)\right)\right]$$

$$c_t+(1+\tau_t)I_t^c q_t^{1i}+\int_{-\infty}^{\infty}q_t^1(\theta_t)k_t^1(\theta_t)d\theta_t=\omega_t n_t+\int_{-\infty}^{\infty}q_t^0(\theta_t)k_t^0(\theta_t)d\theta_t+T_t$$

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

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

2) The producer of the consumption good satisfies (firm's first order conditions)

$$n_t(\theta_t)=N_t^{\alpha}e^{\theta_t}/\overline{K}_t$$

[10] When running numerical simulations with a standard log utility function for leisure, the main results remain qualitatively unchanged.

$$\omega_t(1-\tau_t^{\varpi}) = \alpha A\left(\frac{\overline{K}_t}{N_t}\right)^{1-\alpha}$$

$$q_t^1(\overline{\theta_t}) = s$$

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

3) The intermediary satisfies

$$I_t^i = q_t^{1i} I_t^c$$

4) The government budget constraint satisfies

$$\tau_t I_t + \tau_t^{\varpi}\varpi_t N_t + \pi_t \int_{-\infty}^{\infty} k_t(\theta_t)d\theta_t = T_t$$

5) And markets clear

$$c_t + I_t = Y_t + S_t \tag{15}$$

4. Numerical evaluation

We analyze both steady states under alternative distortions and, for each distortion, the transitional path following a leading-edge technology shock. To approximate actual experiences and to assess the robustness of the results we simulate equilibria for a wide range of policy values.

Numerical equilibria are solved using a three-step strategy. First, we compute the non-stochastic steady state equilibrium variables. Second, we log-linearize the system of equations that characterize the solution around the long-run values of the equilibrium elements. Third, we apply the method of undetermined coefficients described in Christiano (1998) in order to recover the coefficients of the individual policy functions. Because the economy exhibits unbounded growth most of the variables are not stationary. Thus, when solving the equilibrium we scale the non stationary variables by their long-run growth rate. Then, a mapping takes the solution from the scaled objects solved for in the computations to the unscaled objects of interest.

We can separate the parameters in three types, given by the following vectors: aggregate parameters $\{\beta, \delta, \kappa, \mu_z, \alpha, s\}$, plant specific parameters $\{\sigma, \sigma_\theta\}$, and policy parameters $\{\pi, \tau, \sigma_\tau, \rho_\tau, \tau^{\varpi}\}$.

In what follows time is measured in years. Thus, we use a discount factor of 0.95, consistent with a net real interest rate of 5% yearly; the depreciation rate is set at $\delta = 0.06$; the share of labor incomes to output, α, is 0.7, following Gollin (2002).

The aggregate parameters are calibrated as in a representative firm economy. Long-run growth is given by $\mu_z(1-\alpha)/\alpha$, which, since population is stationary, also represents the growth rate of income per capita. Thus, to have an annual trend growth rate of 2%, and given α, we use μ_z equal to 4.5%. The marginal utility of leisure, κ, determines the fraction of available time allocated to labor. We chose κ consistently with N equal to 0.33. The irreversibility s is fixed at 0.9 in the benchmark equilibrium. Then, different values of s will be associated to simulations for different levels of development.

Plant specific parameters are proportional to those used in Campbell (1998). There are two reasons to do so. First, long series of plant level data are generally not available for a large sample of countries. Second, we see our economies as equal in all respect but policies and the developmental level – represented by the irreversibility s. We use the U.S. as our undistorted long-run developed benchmark. The parameters used by Campbell (1998) do a good job generating a distribution of firm's productivities for the U.S. economy, but they fail to capture the larger dispersion of individual productivities observed in developing economies (as reported by Bartelsman, Haltiwanger, and Scarpetta, 2004). Thus, in order to find meaningful values for the productivity threshold (i.e., values of theta bar with strictly positive measure) we must use a substantially larger variance. We use values for σ_θ and σ twice as large as those used by Campbell (1998).

Campbell (1998) sets parameter values to match the moments of plant dynamics using data from the Annual Survey of Manufactures of the U.S. Department of Census. Although we refer to production units as plants in our model, investment projects provide a better description of them. Thus, an entry or an exit in our model might occur within an actual plant, and might not be captured by actual data. In this sense, our model naturally generates much more dynamics than actually observed in the data. Nevertheless, our parameterization underestimates the true variance of investment projects, as we match our model's moments using plant level data. Had we used the variability of entry and exit of projects across and within plants, our results would have assigned a much larger role to reallocation and restructuring as a source of transitional growth.

Policy parameters are also difficult to calibrate since comparable series for plant level distortions are typically not available across countries. These distortions are intended to capture different regulations that reduce competition, raise the costs of firm formation and slow down technological adoption. They may also represent other impediments to the natural process of reallocation across firms such as financial markets imperfections. In general, any policy that affects current and expected productivity, interfering with the natural process of birth, growth, and death of firms, will have a detrimental effect on aggregate growth. For instance, as the cost of entering and exiting the economy increases, the distribution of firms is altered: too many inefficient firms remain in the market and too few potentially more efficient firms enter the market. As a result, both the reshuffling of resources from less to more efficient firms and the adoption of the leading edge technology are impeded.

Specifically, we will simulate equilibria considering three different policy distortions: a red-tape cost, π; a tax on investment, τ, in our model equivalent to a tax on technological adoption; and a labor income tax, τ^{ϖ}. We will also consider a developmental distortion, represented by the irreversibility parameter, s. This parameter affects the adjustment cost of investment and represents barriers such as poor governance or lack of education.

To quantify the magnitude of these distortions for different countries we use the Doing Business database provided by the World Bank. Two specific indexes are of interest for the purpose of our paper: the cost of starting a business as a percentage of per capita income, and the percentage of the initial investment that is lost when a firm decides to exit the market.[11] We take the values provided by these indexes as lower bounds since we are not considering other costs – included in the Doing Business database -, since the mapping of those values to our model economy is not clear.

5. Steady state analysis

In this section we compare steady state equilibria to measure the impact of developmental and regulatory distortions on output levels.[12] We calibrate the policy parameters to match data from the World Bank Doing Business database 2007. We choose to use data for 2007 to ensure GDP figures are not preliminary. For consistency, the distortion indexes are also taken from 2007.

First, labor income taxes do not affect the dynamics of the model.[13] That is, two economies, one with a 0% labor taxes and another with a large labor tax, will adopt new technologies at the same rate. Moreover, data from the World Bank show that labor costs are unrelated to the differences in GDP per capita of the U.S. and a large sample of economies.[14] There is a strong negative association between GNI relative to the U.S. and entry and exit barriers, however. Figures 4 and 5 show this evidence. Therefore, in this section we focus on the policy parameters related to firms' entry and exit decisions.[15]

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[11] For a detailed description of its construction see Appendix 2.

[12] From now on we will refer to income and output as GDP. And most of the time, GDP will represent the per capita indicator.

[13] This is true only for labor distortions that affect exclusively the marginal decisions. Other labor distortions, such as firing costs, which affect the exit decision, are consider in our analysis as exit costs, and therefore are captured by the irreversibility parameter s.

[14] Prescott (2005) shows that the increase in the income gap between the U.S. and Europe, observed since the 1970s, is due to a reduction in hours worked in Europe. He claims that differences in their labor income taxes may explain the differences in hours worked. However, Rogerson (2007) argues that to assess the effects of tax rates on aggregate hours of market work is essential to consider how the government spends tax revenues.

[15] In the next section we will consider the labor income tax, when analyzing the dynamics following a leading-edge technology shock.

Second, as it is obvious from the feasibility condition in equation (15), the analogous to GDP per capita in our model economy is $Y+S$, not Y by itself. That is, the "transformation" of plants back into the *numeraire* is a production process itself which entails the loss of $1\text{-}s$ parts of the original components of the plant. Thus, in what follows we refer to GDP per capita as Y+S in the model economy.

Figure 4. Entry and GNI

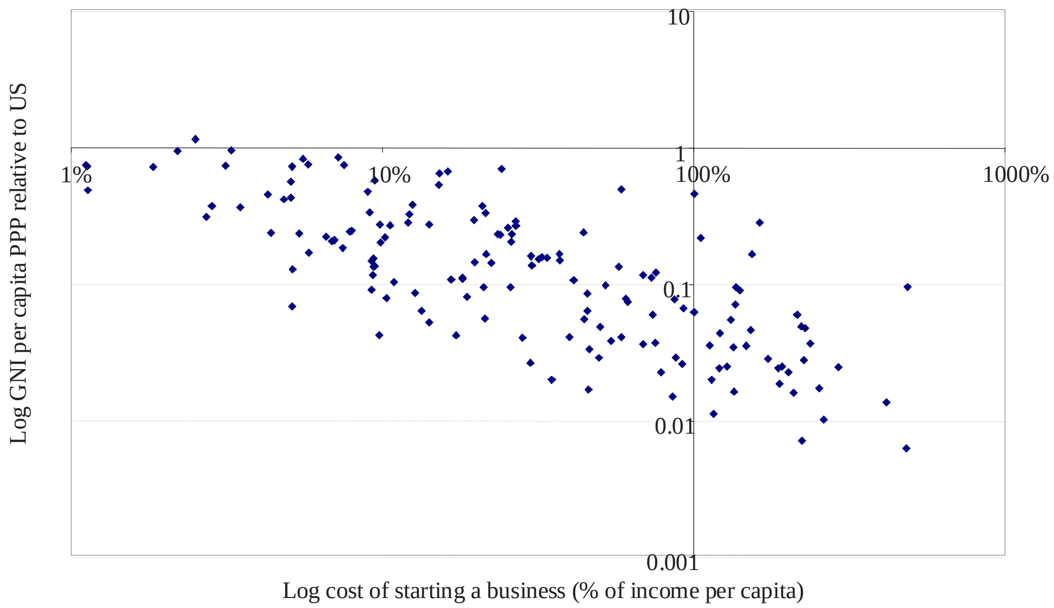
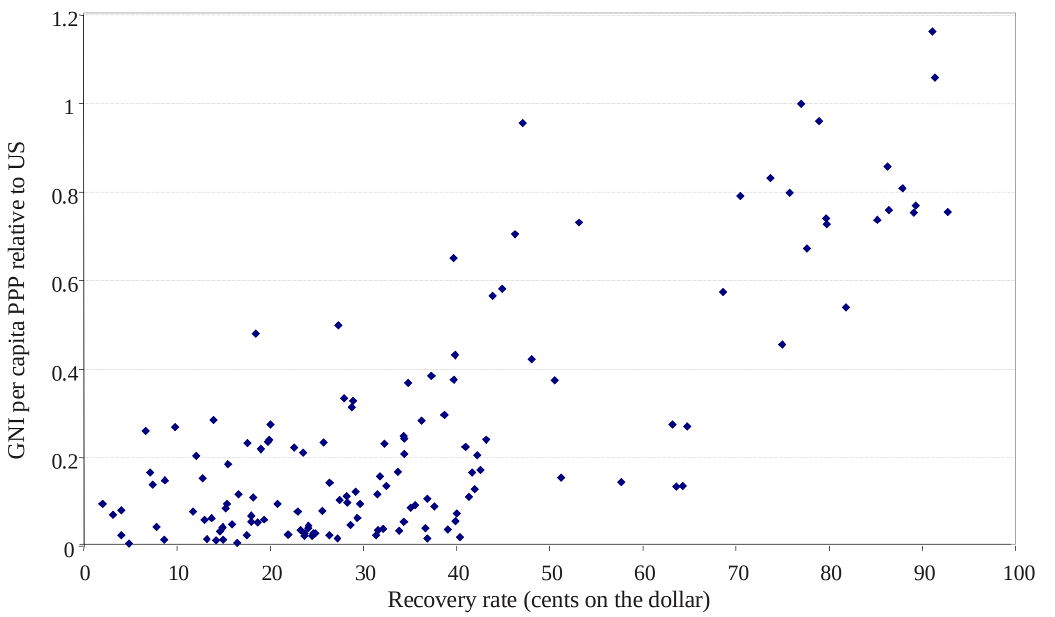


Figure 5. Exit and GNI



The first policy distortion we consider is a tax on investment, τ. Table 2 shows the ratio of GDP relative to the efficient economy under different combinations of τ and the developmental distortion, s.[16] Two shortcomings with the simulation of this policy emerge: first, even for extreme values of the investment tax, the simulated disparity in income per capita is far (too short) from the actual disparity observed in the data.[17] Of course, including additional (simultaneous) taxes, as labor income taxes, would increase the generated disparity in the model. A tax on labor income, however, would show up through differences in hours worked. There is a weak empirical correlation between differences in hours worked and differences in GDP per capita across countries (see Hsieh and Klenow, 2009, and footnote 12), however. Moreover, even if the above were not an issue, it would be at least problematic to construct a meaningful mapping from entry barriers (as described in Appendix 2) to a linear tax on investment. Thus, we focus on a lump sum tax on the operation of plant, π.

Table 2. GDP relative to efficient GDP
(combinations of investment tax and exit barriers)

τ \ s	**0.9**	**0.7**	**0.5**	**0.3**	**0.15**
90%	0.6	0.59	0.58	0.57	**0.56**
70%	0.63	0.62	0.61	0.59	0.59
50%	0.68	0.66	0.65	0.63	0.62
30%	0.74	0.72	0.69	0.67	0.66
10%	0.86	0.79	0.76	0.73	0.71
0%	1	0.84	0.8	0.76	0.74

Table 3 presents selective statistics on entry and exit distortions for Latin America and the 183 countries included in the Doing Business database.

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[16] From now on an economy is said to be efficient when all taxes are zero and the scrap value s is 0.9. This value for s is consistent with the data for the U.S., our benchmark for the developed economy.

[17] While the poorest economy generated by the model (with s = 0.15 and τ = 90%) has a 56% GDP of the efficient economy, African countries, for instance, have on average a GDP per capita based on purchasing-power-parity (PPP) that is only 5.3% that of the U.S. This much larger gap, however, may be explained by reasons other than policy distortions, like external and internal violent conflicts.

Table 3. Selected statistics Doing Business (2007)*

	Latin America and the Caribbean			Whole Sample		
	Entry		Exit	Entry		Exit
	Cost (% of GDP pc)	Time (days)	Recovery rate (cts. on US$)	Cost (% of GDP pc)	Time (days)	Recovery rate (cts. on US$)
Average	52.3	71.3	25.6	106.3	46.2	30.8
Median	30.2	43.0	23.7	24.3	34.0	27.3
Minimum	0.8	7.0	0.0	0.0	2.0	0.0
Maximum	252.4	694.0	64.3	6,375.5	694.0	92.7
St.Deviation	57.4	123.5	20.6	491.3	59.6	24.9
P90	136.8	141	57.7	203.9	87.5	75.3
P10	9.8	14	0.0	3.21	11.7	0.0
US Economy	0.8	6.0	77.0	-	-	-

(*) See Appendix 2 for a detailed description of the objects.

Table 4 presents the simulated income when red tape, π, are in place. Now, the model does a much better job replicating the income heterogeneity observed in the data. The poorest country reaches an income per capita that is only 30% of the one observed in the efficient economy.

Table 4. GDP relative to efficient GDP
(combinations of red tape and exit barriers)

	GDP relative to efficient GDP					π / GDP for combinations				
π \ s	**0.9**	**0.7**	**0.5**	**0.3**	**0.15**	**0.9**	**0.7**	**0.5**	**0.3**	**0.15**
0.9	0.35	0.32	0.31	0.30	0.30	4.23	4.59	4.75	4.86	4.93
0.7	0.38	0.35	0.34	0.33	0.32	2.98	3.26	3.38	3.47	3.53
0.5	0.44	0.4	0.38	0.37	0.36	1.88	2.06	2.15	2.23	2.27
0.3	0.52	0.47	0.44	0.42	0.41	0.94	1.05	1.11	1.16	1.19
0.1	0.72	0.62	0.57	0.53	0.51	0.23	0.26	0.29	0.31	0.32
0	1	0.8	0.69	0.63	0.59	0	0	0	0	0

To express π in units of GDP, the second panel of Table 4 shows the full range of values for this operational cost as a fraction of GDP per capita. The figures go from zero in the efficient economy to almost 5 times GDP per capita when π is 0.9 (our less efficient economy). This last number is in fact well inside the range provided by the World Bank in its Doing Business database. They estimate the cost of opening a business in Latin America (in units of GDP per capita) in a range that goes from 0.1 for the 10th percentile to 1.4 for the 90th percentile (see Table 3). And this index does not include other costs, such as bribes and the days it takes to start a business.[18] Thus, the cost of opening a business as defined in Appendix 2 should be interpreted as a lower bound of the actual total cost. With respect to the value of s, again from Doing Business, the recovery rate of the initial investment per unit of dollar ranges from almost zero for the 10th percentile to 0.753 for the 90th percentile (with a maximum of 0.927).

The production function used in Table 4 is $Y=\overline{K}^{1-\alpha}L^{\alpha}$, where $\overline{K}$ is effective capital. However, in order to be able to compare the model's output with its empirical counterpart, we can rewrite the production function as $Y=(A\cdot K)^{1-\alpha}(h\cdot L)^{\alpha}$, where K is an index of "number of machines", A the average productivity of each machine, and h is the average productivity of each hour worked (human capital). Thus, from a standard development accounting decomposition, we can represent the income per capita gap between two economies by

$$\frac{Y^P/P^P}{Y^R/P^R}=\frac{L^P/P^P}{L^R/P^R}\times\frac{h^P}{h^R}\times\left(\frac{A^P}{A^R}\right)^{\frac{1-\alpha}{\alpha}}\times\left(\frac{K^P/Y^P}{K^R/Y^R}\right)^{\frac{1-\alpha}{\alpha}}, \tag{16}$$

where P stands for population and the superscripts P and R stand for poor and rich respectively.

For example, using Table 4, when π = 0.9 and s = 0.15, the ratio $\frac{Y^P/P^P}{Y^R/P^R}$ is 0.3. From equation (16), this ratio is explained exclusively by the last two terms,

$$\left(\frac{A^P}{A^R}\right)^{\frac{1-\alpha}{\alpha}}\times\left(\frac{K^P/Y^P}{K^R/Y^R}\right)^{\frac{1-\alpha}{\alpha}}, \tag{17}$$

since we are assuming $\frac{L^P/P^P}{L^R/P^R}=1$ and $h^P=h^R=1$. Thus, all the differences in income per capita are accounted for by changes in the effective capital-output ratio, that in turn, can be decomposed in changes in the capital-output ratio and changes in the average productivity. In this sense our model is a theory of endogenous TFP. It allows us to quantify the impact of distortions not only on the main macroeconomic variables, but also on the average productivity of the economy. Of course, when contrasting the model empirically, what proportion corresponds to A and which one to K will depend on how K is computed. One alternative is to compute the total "stock of machines" in the

[18] The Bribe Payers Index, published by Transparency International, supports much higher bribes in developing economies than in developed ones.

economy without weighting by productivity. The other, is to use the standard method of perpetual inventories. That is, to estimate the implicit stock of capital generated by a given stream of investment, given a depreciation rate. Once we have a value for the capital stock, the subjacent index of average productivity would be given by $A = K / \overline{K}$. We will return to this issue in the next section, when we discuss the calibration used for simulating transitional dynamics.

Table 5 illustrates another interesting feature of the model: the **complementarity** of policies. On the one hand, as we can see from the upper right corner of panel 1 in Table 4, improving a country's development (increasing s) when other barriers are kept constant at a high level, has almost no impact in GDP per capita. In the same way, reducing the entry barriers when the economy exhibits a low level of development has a minimal impact in GDP per capita. On the other hand, from the lower left corner of panel 1 in Table 4, reducing entry barriers when the economy has a high level of development has a sizable effect in GDP. And the result holds when the level of development is increased while barriers to entry are kept low.

Table 5 shows the change in output when the red tape are reduced, for different levels of s, and as a proportion of the original output level. The higher the s and the lower the red tape, the higher the output gain as a proportion of the original output level. For instance, to eliminate the tax given an s = 0.9 and a 10% operating cost (that is, to move towards an efficient economy), generates a 39.8% of output gain. If s = 0.15, the same red tape change would have produce an output gain of only 16.6% of the original output level. And since economies with lower taxes and higher s have larger output levels, the absolute gains in output are much larger the closer to the leading edge technology the economy is.

This pattern regarding the change of policy is true everywhere: the higher the development level (the smaller the red tape), the larger the absolute value of the theoretical derivative of GDP with respect to the entry tax (development level). This complementarity is consistent with the empirical findings presented in Section 2. And the policy implication is clear: the benefits from market reforms are largely reduced if distortions, regulatory as well as developmental, are not ubiquitously eliminated.

Table 5. Changes in output with respect to the initial level

π s	0.9	0.7	0.5	0.3	0.15
0.9 to 0.7	10.5%	9.6%	9.3%	8.9%	8.7%
0.7 to 0.5	13.5%	12.7%	12.0%	11.3%	10.9%
0.5 to 0.3	19.4%	18.4%	16.7%	15.4%	14.6%
0.3 to 0.1	37.2%	32.4%	27.5%	24.3%	22.4%
0.1 to 0	39.8%	29.1%	22.5%	18.7%	16.6%

6. Simulations

Our theory proposes a simple explanation for poverty. Some countries are poorer than others due to barriers – developmental and regulatory - to technology adoption. As long as these barriers remain in place, countries continuously lagged behind the world leading-edge technology. The mechanism does not require new technologies to be fully blocked, since slowing down this adoption process is enough to account for most of the observed income disparity across countries. At the end, all technologies are fully adopted by all countries: all that matters to account for income disparities at a moment in time is the speed at which different economies adopt new technologies.[19]

This section analyzes in more detail both, the steady state and the dynamics of two different economies, one efficient, the other distorted. First, we present a development accounting exercise. We find that our theory accounts for 3/4th of the observed income per capita gap. Then, we analyze the dynamics of the efficient and the distorted economies after facing a positive leading-edge technology shock. The dynamics of our model exhibit a pattern consistent with the empirical evidence.

The benchmark equilibrium is represented by an economy without regulatory distortions and a low level of developmental distortions (s = 0.9) that faces a permanent and exogenous increase to the level of world knowledge. We calibrate distortions to represent Latin America and the Caribbean, our developing economy. This selection is for convenience purposes. Latin America has been mostly free of major violent internal conflicts and wars among countries.[20] IMF data from the World Economic Output database show that the average income per capita of Latin America is currently close to 25% of the income per capita in the U.S. Moreover, the World Bank Doing business indexes show that its entry cost is close to a half of its GDP per capita (only 0.7% of GDP per capita in the U.S.), and the investment recovered after a firm exits is 30% (88% in the U.S.).

This distortion parameterization generates a simulated ratio of GDP per capita between Latin America and the U.S. of 0.5, still twice the ratio actually estimated by the World Bank. However, as we previously mentioned, the entry cost index does not include other costs like the duration of the procedure (an average of 67 days in Latin America while only 6 days in the U.S.) and bribes. Thus, we choose to set $\pi = 0.25$, which is equivalent to 0.9 GDP per capita. In addition, our interpretation of s goes beyond that of Appendix 2. Another aspect related to low development that increases the reallocation costs is the lack of human capital, for instance. Hence, we also consider the 0.3 recovery rate per unit as an upper bound.

As shown in Table 4, the income difference accounted for when using these two policies falls short of the observed one (0.44 in the model and 0.25 in the data). In addition, in Table 4 we have assumed that the proportions of hours worked are the same

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[19] Therefore, in the long run all countries should grow at the same rate, although differences in GDP per capita levels would remain.

[20] The exceptions are Colombia and Haiti.

in all economies. And as pointed out by Caselli (2005), the correlation between income per capita and the proportion of hours worked among countries is almost zero. Hence, having the same hours worked in both, developed and developing economies, is empirically consistent. However, it does not follow that the effective labor (per hour worked) in both economies is the same. In fact, there are measurable differences in human capital, which Caselli (2005) estimates in a factor of 2 for economies in the 90th and 10th percentile of income per capita. That is, the most developed economies would have twice as much human capital as a representative developing one. Since the distorted economy that we are calibrating is above the 10th percentile we use a factor of 1.67. This implies that, given $\alpha = 0.7$, our representative developing economy should be scaled down by 0.71.[21] The full parameterization is summarized in Table 6.

To illustrate, we calculate the implicit development accounting decomposition. There two ways to decompose the effective capital contribution, depending on how the capital stock is estimated. The first approach is to estimate the capital stock "adding" all the machines in the economy without weighting them by their productivity, i.e., $K = \int_{-\infty}^{\infty} k_t(\theta) d\theta$. Using equation (16) we obtain,

$$\frac{1}{3.3} = \frac{1}{1} \times \frac{1}{1.67} \times \left(\frac{1}{2.06}\right)^{\frac{1-\alpha}{\alpha}} \times \left(\frac{1}{2.4}\right)^{\frac{1-\alpha}{\alpha}} \tag{17}$$

That is, the model generates a capital-output ratio 2.4 times larger in the developed economy than in the developing one, and a TFP that is more than twice as big in the former, than in the latter. Thus, our model can endogenously generate both, empirically reasonable aggregate productivity and capital-output ratio differences. How does this decomposition change when the capital stock is calculated using the perpetual inventory method? The following equation shows the differences.[22]

$$\frac{1}{3.3} = \frac{1}{1} \times \frac{1}{1.67} \times \left(\frac{1}{1.61}\right)^{\frac{1-\alpha}{\alpha}} \times \left(\frac{1}{3.1}\right)^{\frac{1-\alpha}{\alpha}} \tag{18}$$

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[21] This scale factor should not be confused with the familiar TFP, A. In this paper A is endogenous is determined by the process of innovation.

[22] In steady state the method of perpetual inventories implies $K = \frac{I}{\delta + \lambda}$, where λ is the economy's growth rate.

Table 6. Parametric specification		
Aggregate parameters	***Parameter***	***Value***
Discount factor	β	0.95
Fraction of steady state hours worked	N	0.33
Labor share	α	0.7
Depreciation rate	δ	0.06
Leading edge technology drift	μ_ζ	0.045
Plant level parameters		
Standard deviation of shock to incumbents	σ_θ	0.06
Standard deviation of shock to startups	σ	0.06
Simulation parameters		
Leading edge technology shock	ε_ζ	0.045
Efficient (developed) economy		
Irreversibility (developmental level)	S	0.9
Red tape (benchmark value)	π	0%
Labor income tax (benchmark value)	τ	15%
Distorted (developing) economy		
Irreversibility (developmental level)	S	0.3
Red tape (benchmark value)	π	0.25 (0.9 GDP pc)
Labor income tax (benchmark value)	τ	25%

The contribution of capital increases from 2.4 to 3.1, while the contribution of TFP decreases from 2.06 to 1.61. Again, the question is which one generates empirically plausible numbers. Notice that in both cases the product of the factors gives the same value (around five) which is the change in the effective capital – output ratio difference. The elimination of the barriers would produce and increase in aggregate productivity in the range 60%-100%, and an increase of the capital-output ratio in the order of 140%-210%, as measured in the data. Nevertheless, this development accounting provides no information with respect to the individual impact of policies on income per capita. For instance, how much would the income gap between Latin America and the U.S. decrease if human capital in both economies is equalized? Table 7 presents this accounting.

First, given the observed differences in human capital, and the developmental and regulatory distortions calibrated from the Doing Business database, the model simulates a ratio of income per capita for Latin America to the U.S. of 0.32. The actual ratio from World Bank data set is 0.25. That is, the simulated gap, measured as the simulated difference in GDP per capita between the U.S. and Latin America as a fraction of the U.S. GDP per capita, is 90% of the actual gap (a ratio of GDP per capita of 0.68 instead of 0.75). Since we do not have a theory for human capital differences – our model takes exogenously the reported differences in human capital -, the lack of development and distortions to the extensive margin (entry and exit firm decisions) account for a gap of 0.56 (since human capital explains 0.12). Thus, our mechanism accounts for 75% of the gap in GDP per capita between Latin America and the U.S.

But a second finding is more striking: a half of the simulated gap is accounted for by the complementarity of reforms. As mentioned above, equalizing human capital reduces the gap by 0.12, equalizing the irreversibility level reduces the gap by 0.07, and eliminating the red tape distortions reduces the gap by 0.15. Thus, adding these distortions individually, we explain only 0.34 of the 0.68 simulated gap. The 0.34 left is explained by the simultaneous implementation of these reforms, that is, by their **complementarity.**

Table 7. Simulated development accounting

(Including human capital differences)

Variable	GDP pc gap/ U.S. GDP	% of gap
Total simulated gap (actual gap is 0.75)	0.68	100%
Contribution of equalizing:		
Sum of individual effects	**0.34**	**50%**
- Catching up due to human capital	0.12	17%
- Cost due to exit (s = 0.9, not 0.3)	0.07	11%
- Entry barriers (π = 0, not 0.25)	0.15	22%
Complementarities	**0.34**	**50%**

The relative contribution of each item in Table 7 could be affected by the **complementarity** between human capital and the other policies. To stress the robustness of our finding, we repeat the accounting, but now keeping the level of human capital equal in both economies. As shown in Table 8, quantitatively and qualitatively the findings remain: a half of the reduction in the GDP per capita gap is accounted for by eliminating the distortions simultaneously.

As already mentioned, our simulations consider an entry barrier that is equivalent to 0.9 GDP per capita, larger than the figure provide by the Doing Business database 2007, which is close to 0.5 GDP per capita. This World Bank figure, however, does not include bribes and the cost due to the delay in starting the business. We do not have information on brides as a fraction of GDP per capita in Latin America. The number of days necessary to start a business is 71 in Latin America. That is close to 27% of the total working days in a year. If production is distributed uniformly during the year, one could use an entry cost, excluding brides, of 0.77 GDP per capita, for instance. Thus, to check the robustness of our result we run a simulation with an entry cost of 0.5 GDP per capita, the lower bound for this distortion. Table 9 shows this new development accounting. Now, our theory accounts for 85% (with an entry cost 0.9 GDP per capita we explained 90% of the gap, as shown in Table 7) of the observed gap, and the role of complementarities remains qualitatively unchanged.[23]

Table 8. Simulated development accounting

(With the same human capital)

Variable	GDP pc gap/ U.S. GDP	% of gap
Total simulated gap (actual gap is 0.75)	0.56	100%
Contribution of equalizing:		
Sum of individual effects	**0.29**	**52%**
- Cost due to exit (s = 0.9, not 0.3)	0.11	19%
- Entry barriers (π = 0, not 0.25)	0.18	33%
Complementarities	**0.27**	**48%**

Figure 6 shows the impulse response of entry and exit, output and employment to a positive shock of 4.5% to the leading technology (a shock of a one drift size). These figures highlight the mechanism that impedes technology adoption and the reason why a policy maker may be tempted to use it. First, we show the response of investment (entry) to the positive shock to the leading-edge technology. The less distorted the economy is, the faster the adoption of the newly available technology. Initially investment jumps 45% in the undistorted economy, but only 27% if distortions are in place. Notice that since at the end both economies fully adopt this new technology, more adoption occurs later on in the distorted economy than in the undistorted one. Thus, given a level of world knowledge, policies only affect the timing of adoption.[24] The response of exit shows a similar pattern. Exit is initially larger in the undistorted economy than in the distorted one.

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[23] The fraction of GDP per capita gaps accounted for by policy distortions may be underestimated in our simulations. Doing Business indexes show a decreasing pattern in the level of distortions in Latin America during the decade. Then, if distortions affect with a lag, to explain the observed GDP per capita levels in 2007, we should have calibrated distortions to higher levels, as observed previously to 2007.

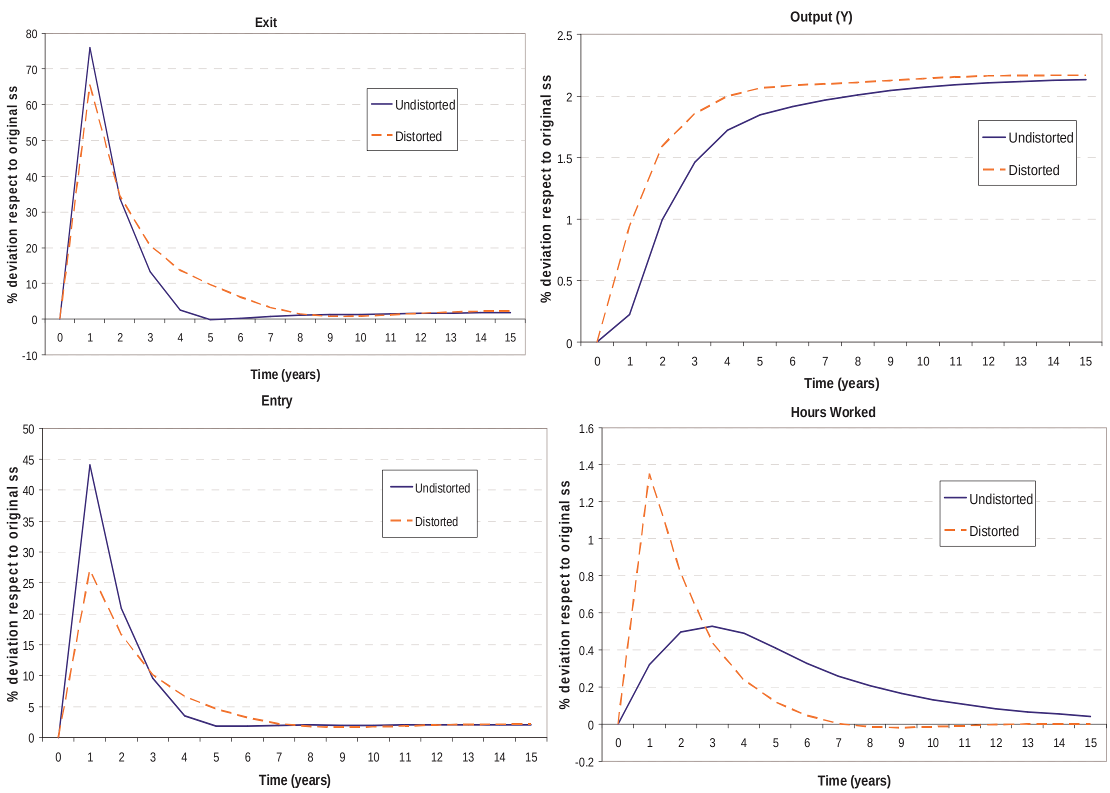
[24] The "inevitable" full adoption of new technologies is implicit in the assumption that long run growth (μ_z) is exogenous and equal in both economies. We think that this assumption reflects accurately the sources of growth, since sooner or later all technological innovations are worldwide adopted.

Table 9. Simulated development accounting
(Including human capital differences and with entry cost 0.5 GDP pc)

Variable	GDP pc gap/ U.S. GDP	% of gap
Total simulated gap (actual gap is 0.75)	0.63	100%
Contribution of equalizing:		
Sum of individual effects	**0.36**	**57%**
- Catching up due to human capital	0.08	12%
- Cost due to exit (s = 0.9, not 0.3)	0.13	21%
- Entry barriers (π = 0, not 0.25)	0.15	24%
Complementarities	**0.27**	**43%**

Therefore, policies that deter entry and exit smooth over time technological progress. The last two panels of Figure 6 illustrate this issue. First, in the distorted economy production (without including salvaged capital) grows "faster" in all periods, that is, it approaches its asymptotic growth rate faster than in the efficient economy. Second, employment in the distorted economy has an initial jump that is three times the one observed in the efficient economy.

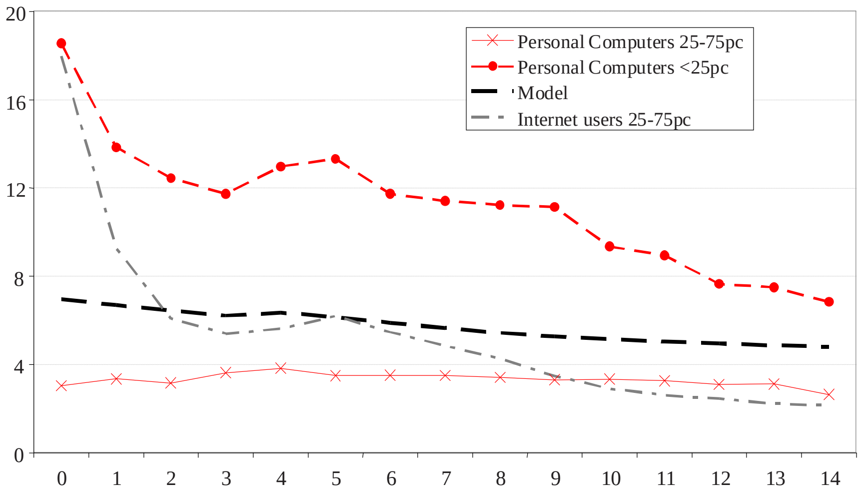
Figure 6. Impulse Responses



To what extent does the model reflect the pattern of investment in new technologies observed in the data? As shown in Figure 2, there are wide and persistent differences in investment among countries. These differences result not only from the regulatory barriers, but also from the gap in income among countries.

To analyze the pattern of investment generated by the model, we construct the accumulated investment for both economies after they are hit by the leading-edge technology shock. Since we want to compare these indicators with other indexes, like personal computers per person or internet usage per person, which are not weighted by productivity, the accumulated investment (or the stock of "new machines") is also calculated without adjusting by productivity. However, given the perpetual inventory method to construct capital, in this case we must adjust not only by the depreciation rate but also by the proportion of machines that are scraped every period. In order to normalized the indexes we compute the ratio of accumulated investment in the distorted economy to the undistorted one. Then, we compare the ratio of personal computers (per 1000 people) in countries that are in or over the 75th percentile of Regulatory Freedom with the same indicator for countries that are between the 25th and 75th percentile and those that are below the 25th percentile, respectively. The results are plot in Figure 7. The model generates a ratio that lies in between the two actual ratios obtained from the data. In addition, they follow a similar pattern: larger at the beginning and slowly decreasing after on, converging to a value of around 4. Analogous calculations were performed using internet usage (per 1000 people). The 75th to 25th-75th percentile follows a similar pattern.[25]

Figure 7. Ratios of Accumulated Investment in New Technologies



[25] The ratio for the 75th to less than 25th percentile is not depicted since is out of scale, starting in values around 1400, but quickly converging to 5.

Figure 8 shows the impulse response under alternative regulatory policies. All changes are normalized with respect to each economy´s initial steady state. Thus, each curve shows the transition from the original steady state - which differs among policies - to the new steady state after the shock to the leading-edge technology has occurred. Thus, we are measuring the impact of technology adoption on the time that it takes to reach the new steady state. Because of the exogeneity of the growth rate, the size of the total (final) jump of output (proportional to the original steady state) is the same in each economy. The difference lies in the number of transitional periods and the speed of convergence. An efficient economy requires six years to (almost) reach the new steady state. But when a 10% investment tax is in place, the convergence requires twice as much (13 years).

Figure 8 can be misleading as to the extent in which the distortions affect the economy since, in all cases, the permanent (proportional) increase ends up being the same. To illustrate this issue we present a different exercise: instead of considering different initial steady states (due to different initial distortions), we consider an initially undistorted economy which is hit not only by the leading technology shock, but also with a simultaneous shock of a particular policy. We consider four kind of possible policy reactions to the leading-edge technology shock: no distortion (efficient economy), entry tax, exit tax, and labor income tax. In each case we assume an increase of 10% in the tax rate that is being considered.

Figure 8. Impulse responses for given steady state

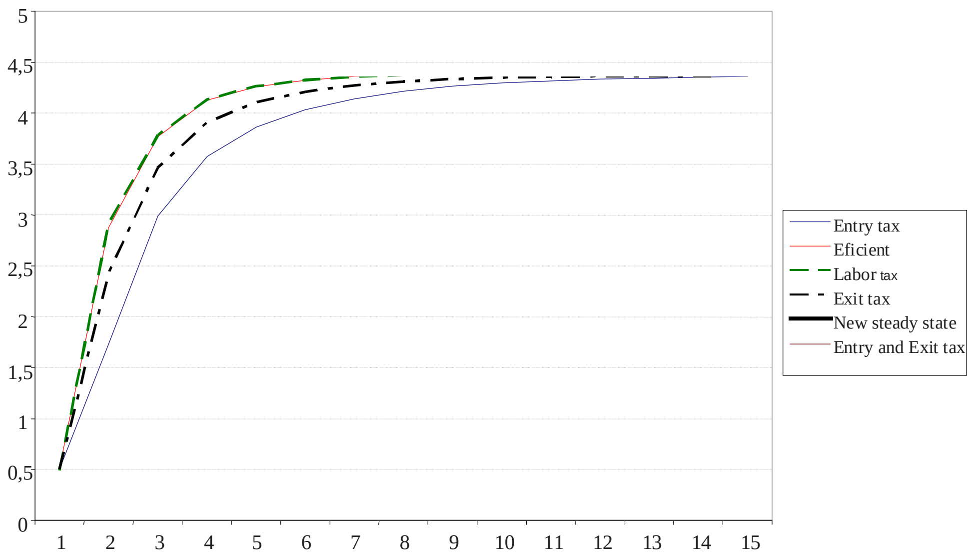
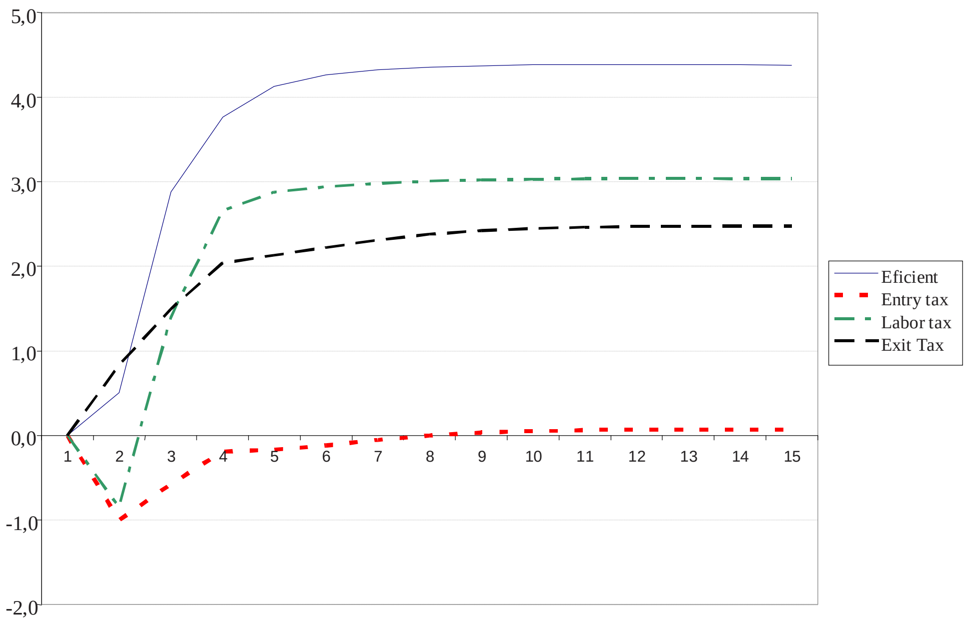


Figure 9 shows that this simultaneous policy reaction affects not only the dynamics of the economy but also its steady state. First, as expected, the absence of any government policy generates the highest new steady state. Second, the increase in the labor income tax only affects the steady state of the economy, but not its dynamics. This is due to the fact that labor income taxation alters only the firm's intratemporal decision rules, not the intertemporal ones.[26] Therefore, the dynamics of an economy with labor taxation mimics that of the efficient economy. Third, the exit tax policy illustrates why it could be tempting for a policy maker to use this kind of policy. Even though in the long run the economy ends up in a lower steady state, in the first period the distorted economy grows faster than the undistorted one. Finally, the policy that affects directly the entry decision could not only generates a bad short term outcome (output drops instead of growing) but also could fully compensate the advantage of the availability of the new technology. That is, the new steady state is approximately the same as the old one.

Figure 9. Impulse responses allowing different steady states



7. Concluding comments

We have linked microeconomic rigidities and technological innovation, to provide a theory of development.

Since world knowledge expands continuously, economies that keep obstacles to innovation permanently lag the leading-edge technology, and thus, the leaders' income per capita. In particular, when government-imposed regulations or developmental barriers deter the ongoing process of resource reallocation and firm creation and

[26] As mentioned before, if the labor efficiency wedges were modified to include other kind of distortions, such as firing cost, this would no longer be true.

destruction, then technological adoption becomes sluggish and the economy fails to generate enough growth to close the developed-developing gap. Even though all economies end up fully adopting the new technologies, poor economies are always behind.

These regulatory and developmental barriers not only exert an independent effect on technological innovation but also complement each other in this regard: policy-induced regulatory obstacles to firm dynamics limit reallocation, and the shortcomings inherent to underdevelopment, such as poor education and faulty governance, exacerbate the costs of firm renewal. That is, the effect of regulatory freedom on technological innovation is larger the higher the level of economic development, and vice versa.

Our model accounts for 75% of the income per capita gap between Latin America and the U.S. Half of this simulated gap is explained by the barriers individually, the other half by their complementarity.

These results suggest further research on other growth-related issues, such as the timing of the reforms. Market oriented reforms have been extensively undertaken by developing economies during the last two decades. However, most reforms are implemented sequentially, so when one reform is in place other obstacles to reallocation remain. Our theory suggests that the benefits from these market reforms have been substantially reduced when distortions have not been uniformly eliminated. A corollary follows: since resource reallocation implies costly adjustment, sequentially implemented market reforms may end up being reverted in developing economies.

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Data appendix 1. Definitions and sources of explanatory variables

Variable	Definition and Construction	Source
Regulatory Freedom	An index ranging 0 to 10 with higher values indicating less regulated. It is a comprehensive index that captures three areas of regulatory restraints: (i) Domestic credit market; (ii) Labor market; and (iii) Business activities. Each area also has five sub-components. The area of credit market is composed of (a) Ownership of banks; (b) Competition; (c) Extension of credit; (d) Avoidance of interest rate controls and regulations that lead to negative real interest rates; and (e) Interest rate controls. The measure of labor market regulations is based on (a) Impact of minimum wages; (b) Hiring and firing practices; (c) Share of labor force whose wages are set by centralized collective bargaining; (d) Unemployment Benefits; and (e) Use of conscripts to obtain military personnel. Regulation of business activities is composed of following indicators: (a) Price controls; (b) Administrative Conditions/Entry of New Business; (c) Time with government bureaucracy; (d) Starting a new business; and (e) Irregular payments. A score of 1995 by country is used.	Gwartney and Lawson (2006), The Fraser Institute. Data retrieved from www.freetheworld.com.
Governance	An index ranging 0 to 5.5 with higher values indicating better governance. It is a simple average of Law and Order (6 points), Bureaucracy Quality (4 points) and Corruption (6 points) indices. Law and Order are assessed separately, with each sub-component comprising 0 to 3 points. Assessment of Law focuses on the legal system, while Order is rated by popular observance of the law. The rating of Bureaucracy Quality is based on the strength and established mechanism of the bureaucracy to govern without drastic changes in policy and to be autonomous from political pressure. Corruption covers a wide range of forms of corruption in the political system, from bribes to excessive patronage, nepotism and secret party funding. An average of 1994-1996 by country is used.	ICRG. Data retrieved from www.icrgonline.com.
Schooling	Average schooling years in the population aged 15 and over. A score of 1995 by country is used.	Barro and Lee (2001).

Data appendix 2. Description of the Doing Business database

Indexes: (1) cost of starting a business as a percentage of per capita GDP and (2) percentage of the initial investment that is lost when a firm decides to exit. According to the World Bank methodology these indexes include:

(1) Starting a Business: *"… Cost is recorded as a percentage of the country's income per capita. It includes all official fees and fees for legal or professional services if such services are required by law. Fees for purchasing and legalizing company books are included if these transactions are required by law. The company law, the commercial code and specific regulations and fee schedules are used as sources for calculating costs. In the absence of fee schedules, a government officer's estimate is taken as an official source. In the absence of a government officer's estimate, estimates of incorporation lawyers are used. If several incorporation lawyers provide different estimates, the median re ported value is applied. In all cases the cost excludes bribes."*

(2) Cost of Closing a Business: *"..the recovery rate is recorded as cents on the dollar recouped by creditors through the bankruptcy or insolvency proceedings. The calculation takes into account whether the business emerges from the proceedings as a going concern as well as costs and the loss in value due to the time spent closing down. If the business keeps operating, no value is lost on the initial claim, set at 100 cents on the dollar. If it does not, the initial 100 cents on the dollar are reduced to 70 cents on the dollar. Then the official costs of the insolvency procedure are deducted (1 cent for each percentage of the initial value). Finally, the value lost as a result of the time the money remains tied up in insolvency proceedings is taken into account, including the loss of value due to depreciation of the hotel furniture. Consistent with international accounting practice, the depreciation rate for furniture is taken to be 20%. The furniture is assumed to account for a quarter of the total value of assets. The recovery rate is the present value of the remaining proceeds, based on end 2006 lending rates from the International Monetary Fund's* International Financial Statistics, *supplemented with data from central banks."*