Preliminary and incomplete

Why Are Developing Countries so Slow in Adopting New Technologies?[*]

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Abstract

We analyze the process of technological innovation from the perspective of developing countries. Specifically, we explore how developmental and regulatory impediments to the process of resource reallocation and firm renewal limit the ability of developing countries to adopt new technologies. First, we study how the availability of personal computers and incidence of internet usage --as proxies for technological progress-- are related to regulatory freedom, governance, and schooling in a large cross-section of countries. We find that these characteristics not only exert an independent effect on technological innovation but also complement each other in this regard. We then build a stochastic general equilibrium model with heterogeneous firms subject to idiosyncratic shocks. Technological innovation is modeled as adoption of exogenous productivity shocks requiring firm renewal. Then, we analyze the independent impact of developmental and regulatory barriers and the complementarities of their effects on firm dynamics and the process of technological adoption. As expected, when the process of firm dynamics is undistorted, firms quickly incorporate the advances from shocks to the technological frontier. However, when government-imposed regulations deter the ongoing process of firm destruction and creation, then technological adoption becomes sluggish and the economy fails to generate enough growth to close the developed-developing gap.

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I. Introduction

One of the most important developments in the world economy in the last three decades has been the process of globalization. From the poorest to the most advanced regions, countries are opening up not only to external trade and finance, but also to the flow of new people, new policies, new ideas, and new technologies. Few countries, however, are taking full advantage of the opportunities brought about by globalization. Indeed, there is large diversity regarding the rate of adoption and adaptation of even inexpensive technologies generated elsewhere in the world. This leads to the central question of this paper: why are some countries so slow in adopting new technologies? The answer we propose here focuses on the Schumpeterian process of firm renewal and the potential restrictions to its optimal functioning.

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, macroeconomic growth. The entry and exit of firms, involving the reallocation of resources from less to more efficient firms, 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.

This paper studies how firm dynamics can serve as the mechanism through which technological innovation occurs. If firm renewal is not restrained, domestic enterprises are able to incorporate the advances of a rising technological frontier made available through, for instance, trade and financial liberalization. In contrast, if there are obstacles to the process of resource reallocation, a countries' ability to adopt new technologies can be severely handicapped. Some of these impediments are related to the development status of the economy such as lack of human capital and poor governance, both of 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 private markets, such as excessive labor regulations, subsidies to inefficient sectors and firms, barriers to the establishment of new plants, and burdensome bankruptcy laws. These distortions, and their corresponding 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 between countries are produced as they enact regulatory barriers to the efficient use of available technologies. Bernanke (2005) points out 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 adopting information technologies and suffer from lower productivity growth.

Our contribution in this paper consists of analyzing the process of technological innovation from the perspective of developing countries. For this purpose, we explore how impediments to the process of resource reallocation and firm renewal limit the ability of developing countries to adopt new technologies. 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, which also exacerbate the costs of firm renewal. Moreover, we analyze how these two types of impediments --developmental and regulatory-- interact with each other to affect firm dynamics and, consequently, technological adoption.

The paper is organized as follows. 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 in a country, we study how they are related to regulatory freedom, governance, and schooling in a large cross-section of countries. We find that these characteristics not only exert an 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 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 education and governance-- are modeled as a parameter that affects the adjustment cost of investment. Regulatory barriers are, in turn, modeled as either subsidies to inefficient firms or taxes to labor. Using this framework, we conduct simulation exercises to analyze, first, the independent impact of each developmental and regulatory barrier and, second, the complementarities between the two. We are particularly interested in their effect on firm dynamics and the process of technological adoption. Finally, we offer some concluding remarks and policy implications.

II. Some Motivating Facts

The differences across countries regarding technological adoption are quite large. Studying 115 technologies in 150 countries, Comin, Hobijn, and Rovito (2006) conclude that "within a typical technology, the dispersion in the adoption levels across countries is about 5 times larger than the cross-country dispersion in 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: Only 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 identify the effect of certain initial conditions on recent adoption levels of these technologies.

Before proceeding to this 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 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, we divide countries in three groups on the basis of regulatory freedom. 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 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.

The evidence presented above is suggestive that both developmental and regulatory barriers play a role in explaining technological differences across countries. For more rigorous 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 effect, 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 last one, by regulatory freedom.[1] 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 exogenous 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

[1] 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.

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 suffering some developing countries.

Since we are interested in assessing not only the direct effects of developmental and regulatory characteristics but also 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.[2] Given that the total impact depends on the values of the variables with which regulatory freedom is interacted, it is not really informative to provide a single summary measure of the effect. Instead, it is best to show how this effect varies with governance and schooling. We do so in Figure 3. Specifically, the figure presents the total effect on both personal computers and internet users of a one-standard-deviation change in the regulatory freedom index for the range of sample 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).

Figure 3 shows that if governance and schooling are very low, an increase in regulatory freedom may be counterproductive, leading to lower levels of technological innovation.

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[2] 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,

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

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

Only countries that are sufficiently advanced in governance, institutions, schooling and human capital can take advantage of larger regulatory freedom to speed up the process of technological adoption. Considering the samples in our study, between 60% and 95% of countries in the world are in a position to benefit from regulatory freedom (the percentages depending on the proxies for technological adoption and developmental characteristics under consideration). The rest would require improving their government institutions and population education as they encourage larger regulatory freedom. 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.

III. A model

We use a general equilibrium model with heterogeneous plants, vintage capital, and idiosyncratic shocks, as in Bergoeing, Loayza and Repetto (2004), and based on Hopenhayn (1992) and Campbell (1998). We assume that there exists a distribution of plants characterized by different levels of productivity. In each period, plant managers decide whether to exit or to stay in business. If a plant stays, the manager has to decide how much labor to hire. If the plant exits, it is worth a sell-off value. New technologies are developed every period. Plants face two types of shocks: an idiosyncratic shock to productivity and a shock to the leading edge production process.

In this context, the economy is characterized by an ongoing process of firm entry and exit, and job creation and destruction. Plants may decide whether to exit in order to gain access to the leading edge technology -Schumpeter’s process of creative destruction-, although at the cost of receiving a scrap value for its capital. These investment irreversibilities, as modeled by Caballero and Engel (1999), together with idiosyncratic uncertainty, generate an equilibrium with plants rationally delaying exit decisions. Also, plants may decide whether to exit forever if the economic prospects loom negative.

Within this setting, firms can become more productive over time for two reasons: because they are exposed to better methods of production or because they thrive while others disappear.

Finally, we allow for government policies and other general distortions. In particular, output and investment taxes, labor market policies, and entry costs can be studied. In what follows we consider a specific policy, a subsidy to incumbent firms, to illustrate the role of distortions in our model economy.

A. Consumer´s problem

There is a representative consumer that lives forever and orders consumption and leisure in every period according to $\log(C_t)+\kappa(1-N_t)$. At the beginning of the period the consumer sells her portfolio of plants (at the price $q_t^0(\theta_t)$) and supplies labor to the firm. At the end of the period she consumes, buys productive plants (at the price $q_t^1(\theta_t)$) and new plants (at the price q_t^{1i}). Between periods both, productive and new plants receive an idiosyncratic shock. That is, the consumer solves

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

subject to

$$C_t + I_t^c q_t^{1i} + \int_{-\infty}^{\infty} q_t^1(\theta_t)k_t^1(\theta_t)d\theta_t = \omega_t N_t + \int_{-\infty}^{\infty} q_t^0(\theta_t)k_t^0(\theta_t)d\theta_t$$

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

B. Firm´s problem

At the beginning of the period the firm buys plants from the consumer ($k_t^0(\theta_t)$), hires labor (N_t) and allocates labor among plants ($n_t(\theta_t)$). During the period the firm produces, and capital depreciation takes place. At the end of the period the firm decides which plants to scrap ($\underline{\theta}_t$) and which plants to keep operational. If a plant is scraped, a proportion s < 1 of capital goods is lost. On the other hand, if the plan is kept operational, it is sold to the consumer at the price ($q_t^1(\theta_t)$). Finally, the firm sells the final output and the goods recovered from scraped plants to the consumer, C_t , and to the investment firm, I_t . Thus, the firm solves

$$\underset{\{n_t(\theta_t),k_t^0(\theta_t),\underline{\theta}_t\}}{Max}\left\{\int_{-\infty}^{\infty}k_t^0(\theta_t)e^{\theta_t 1-\alpha}n_t^{\alpha}(\theta_t)d\theta_t + (1-\delta)s\int_{-\infty}^{\underline{\theta}_t}k_t^0(\theta_t)d\theta_t + (1-\delta)\int_{\underline{\theta}_t}^{\infty}q_t^1(\theta_t)k_t^0(\theta_t)d\theta_t \right.$$
$$\left. - \int_{-\infty}^{\infty}q_t^0(\theta_t)k_t^0(\theta_t)d\theta_t - w_t\int_{-\infty}^{\infty}n_t(\theta_t)k_t^0(\theta_t)d\theta_t\right\}$$

where $\int_{-\infty}^{\infty}k_t^0(\theta_t)e^{\theta_t 1-\alpha}n_t^{\alpha}(\theta_t)d\theta_t = C_t + I_t$

is the total output in the economy.

Technology updating

Suppose now that the firm can update each plant's technology after buying it and before the labor allocation and selling decisions are made. Let the function $\gamma(\theta_t)$ be the increase in productivity over θ_t that the firm chooses for each plant with technology θ_t and let $c(\theta,\gamma(\theta),z)$ be the cost function of technology investment. Assume that $c(\theta,\gamma(\theta),z)$ is strictly increasing, differentiable, strictly convex and that $c(\theta,0,z)=0$. Now the firm solves

$$\underset{\{\gamma(\theta_t),n_t(\theta_t),k_t^0(\theta_t),\underline{\theta_t}\}}{Max}\left\{\int_{-\infty}^{\infty} e^{[\theta_t+\gamma(\theta_t)]1-\alpha} n_t^{\alpha}(\theta_t)-w_t n_t(\theta_t)\,d\theta_t+(1-\delta)s\int_{-\infty}^{\underline{\theta_t}+\gamma(\theta_t)} k_t^0(\theta_t)\,d\theta_t+\right.$$

$$\left.(1-\delta)\int_{\underline{\theta_t+\gamma(\theta_t)}}^{\infty} q_t^1(\theta_t+\gamma(\theta_t))k_t^0(\theta_t)\,d\theta_t-\int_{-\infty}^{\infty} c(\theta,\gamma(\theta),z_t)k_t^0(\theta_t)\,d\theta_t-\int_{-\infty}^{\infty} q_t^0(\theta_t)k_t^0(\theta_t)\,d\theta_t\right\}$$

C. Investment sector and market clearing

In addition to the final output firm there exists an investment firm that transforms the aggregate good into productive plants at zero cost. To construct a new plant an investment firm requires one unit of aggregate good; that once constructed, it is sold to the consumer at the price q_t^{1i} . Since the transformation technology exhibits constant returns to scale, the zero profit conditions implies $q_t^{1i}=1$.

Finally, market clearing implies that the amount or resources devoted to investment by the investment firm, I_t , has to be equal to the investment undertaken by the consumer, I_t^c .

In addition, consumption and investment exhaust the total resources in the economy, total output and scraped capital. That is

$$C_t+I_t^C=\int_{-\infty}^{\infty} k_t^0(\theta_t)e^{\theta_t 1-\alpha} n_t^{\alpha}(\theta_t)d\theta_t+(1-\delta)\int_{-\infty}^{\underline{\theta_t}} k_t^0(\theta_t)d\theta_t=\overline{K}_t^{1-\alpha}N_t^{\alpha}+S_t$$

where $\overline{K}_t=\int_{-\infty}^{\infty} k_t^0(\theta_t)e^{\theta_t}d\theta_t$

and

$$S_t=(1-\delta)\int_{-\infty}^{\underline{\theta_t}} k_t^0(\theta_t)d\theta_t$$

If we allow for technology updating there is an additional investment that must be consider in the aggregate market clearing condition.

Let $I_t^T = \int_{-\infty}^{\infty} c(\theta, \gamma(\theta_t), z_t) k_t^0(\theta_t) d\theta_t$,

then the new market clearing condition is

$$C_t + I_t^C + I_t^T = \overline{K}_t^{1-\alpha} N_t^{\alpha} + S_t = Y_t + S_t$$

Definition of the equilibrium: For any fiscal policy $\{T_t, \tau_t^e, \tau_t^w, \tau_t^s\}_{t=0}^{\infty}$, a *Competitive Equilibrium* is a set of contingent plans $\{c_t, I_t^c, I_t^u, S_t, Y_t, N_t, \overline{K}_t\}_{t=0}^{\infty}$, and contingent prices $\{\omega_t, q_t^1, q_t^0, q_t^{1i}\}_{t=0}^{\infty}$ of labor, plants at the beginning of the period, plants at the end of the period, and construction projects, and a vector $\{\overline{\theta}_t\}_{t=0}^{\infty}$ such that, given contingent prices, production and government stochastic processes {z_t, θ_t, τ_t}, at each period *t*:

1) The representative consumer solves

$$\max_{\{c_t, n_t, k_t^1(\theta), k_t^0(\theta), I_t^c\}} \left\{ E_0 \left[\sum_{t=0}^{\infty} \log(c_t) + \kappa(1-n_t) \right] \right\}$$

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

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

2) The producer of the consumption good satisfies

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

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

$$q_t^1\left(\overline{\theta}_t + \gamma(\overline{\theta}_t)\right) = s(1-\tau_t^s)$$

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

$$\left(1-\alpha\right)\left(\frac{\overline{K}_t}{N_t}\right)^{-\alpha} e^{\theta_t+\gamma(\theta_t)}+\left(1-\delta\right)\left[1\left\{\theta_t<\overline{\theta_t}\right\}0+1\left\{\theta_t>\overline{\theta_t}\right\}\frac{\partial q_t^1\left(\theta_t+\gamma(\theta_t)\right)}{\partial\gamma(\theta_t)}\right]=\frac{\partial c(\theta_t,\gamma(\theta_t),z_t)}{\partial\gamma(\theta_t)}$$

$$I_t^u=\int_{-\infty}^{\infty} c(\theta_t,\gamma(\theta_t),z_t)k_t^0\left(\theta_t\right)d\theta$$

3) The intermediary satisfies

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

4) The government satisfies

$$\tau_t^e\int_{-\infty}^{\infty} q_t^1\left(\theta_t\right)k_t^1\left(\theta_t\right)d\theta+\tau_t^w\omega_t N_t+\tau_t^s\int_{-\infty}^{\theta_t} sk_t^1\left(\theta\right)d\theta=T_t$$

5) The market clearing restriction is satisfied

$$c_t+I_t^c+I_t^u=Y_t+S_t$$

Calibration

Most parameter values used in the simulations are standard for the literature. In what follows time will be measure in years, therefore we will use a discount factor of 0.95, consistent with a net real interest rate of 5% yearly. Depreciation rate is set at δ=0.06. Most estimations on the literature fluctuate around this value. The share of labor incomes to GDP, α, used in the following simulations is 0.7. There has been certain disagreement about the right value for this parameter, especially when analyzing developing countries, where National Accounts Calculations seem to be lower. However, this problem we follow Gollin (2002) and assign this differences to measurement problems.

To solve for the numerical equilibria we use a three-step strategy. First, we compute the non-stochastic steady state values for the model variables. Second, we linearize the system of equations that characterize the solution around the long-run values of the variables. Third, we apply the method of undetermined coefficients described in Christiano (1998). To solve the model we scale the variables by the long-run growth rate such that they converge to a steady state. Then, a mapping takes the solution from the scaled objects solved for in the computations to the unscaled objects of interest.

Simulations

Figure 1.

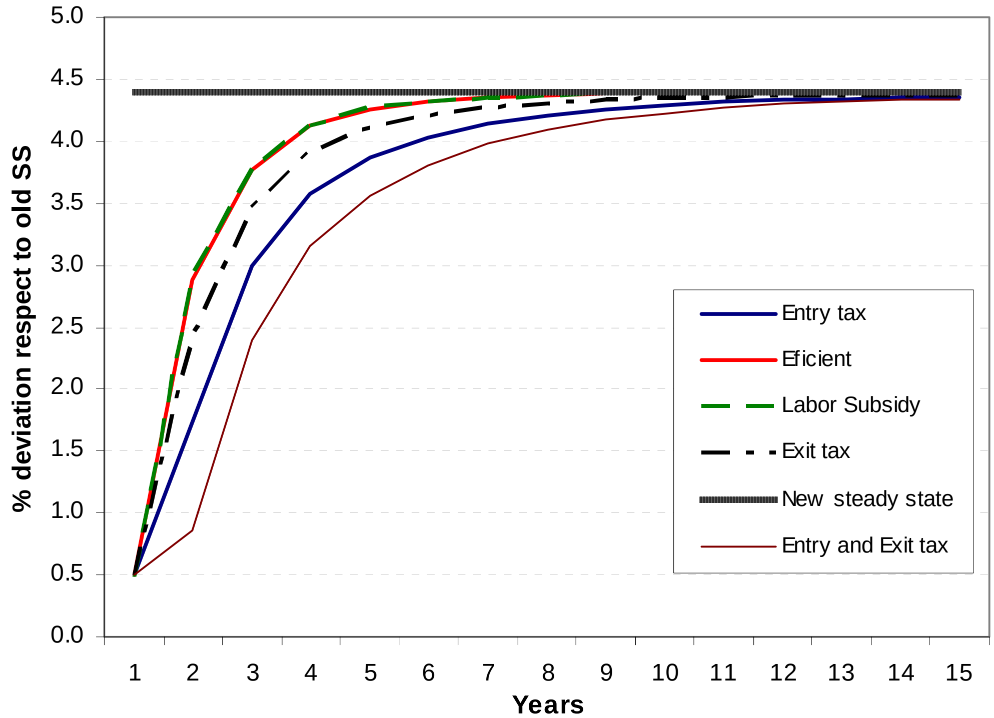


Figure 1 shows the impulse response of output to a shock of 10% to the leading technology under different policies. All changes are detrended, thus each curve shows the transition from the original steady state (which is different for each kind of policy) to the new one. Therefore, we are measuring the rate of technology absorption as the time that it takes to the economy to reach a new steady state. Notice that the magnitude (proportional to the original steady state) of the final jump in each economy is the same; the main differences are in the time that it takes to reach the new steady state and the speed at which this happens.

Since Figure 1 can be misleading as to the extent in which the distortions affect the economy because in any case sooner or later the permanent (proportional) increase is the same. In order to shed light on this issue we perform a different exercise. Instead of considering different initial steady states (due to different initial distortions), we perturb the efficient economy (i.e., without distortions) not only with the leading technology shock but also with a simultaneous shock on each of the policies consider on Figure 1. The magnitudes of the shocks are half of the assumed above. Now since the original steady state is the same in every case the comparisons regarding steady states are meaningful.

Figure 2. (change figure to make red line positive!!)

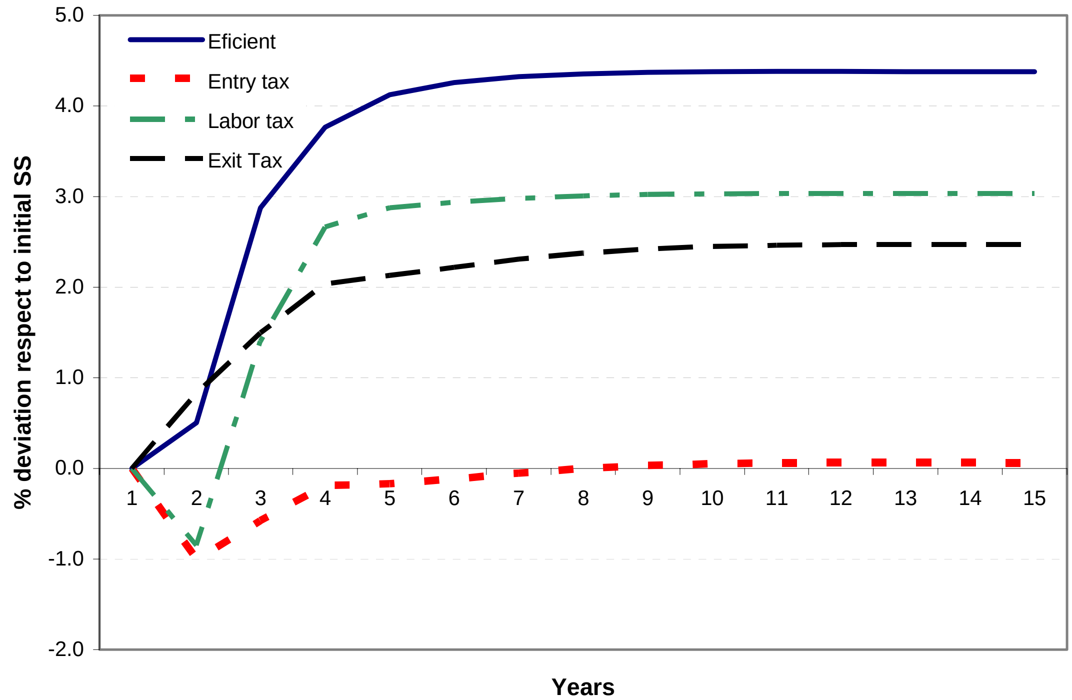
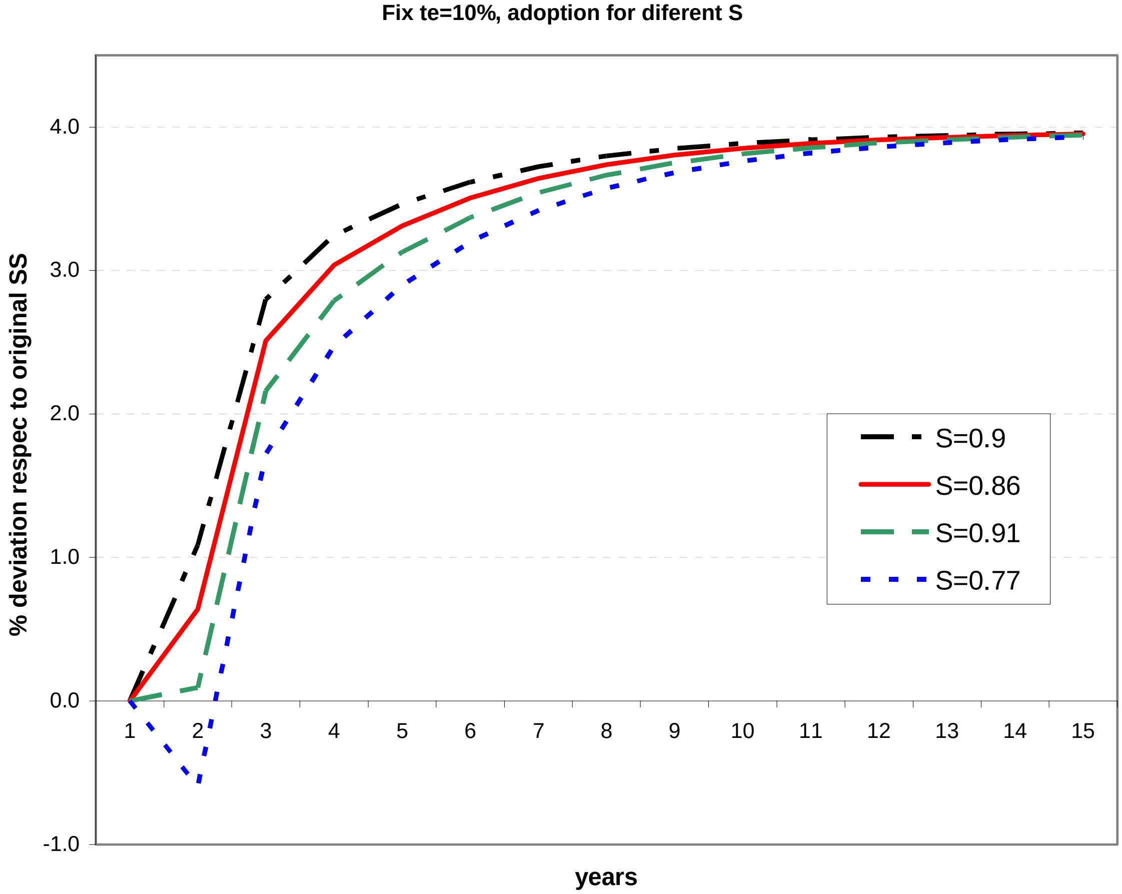


Figure 3 attacks the complementarities issue. Now, each line is the impulse response (the same as in figure 1) to a shock of 10% to the leading edge technology with the same entry tax (set at 10%) but with different scrap values of capital.

Figure 3



Fix te=10%, adoption for diferent S
% deviation respec to original SS
4.0
3.0
2.0
1.0
0.0
-1.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
years
S=0.9
S=0.86
S=0.91
S=0.77

Figure 4 is similar to Figure 3. Now, each line is the impulse response (the same as in figure 1) to a shock of 10% to the leading edge technology with the same exit tax (development barriers, set at 10%) but with different entry taxes.

Figure 4

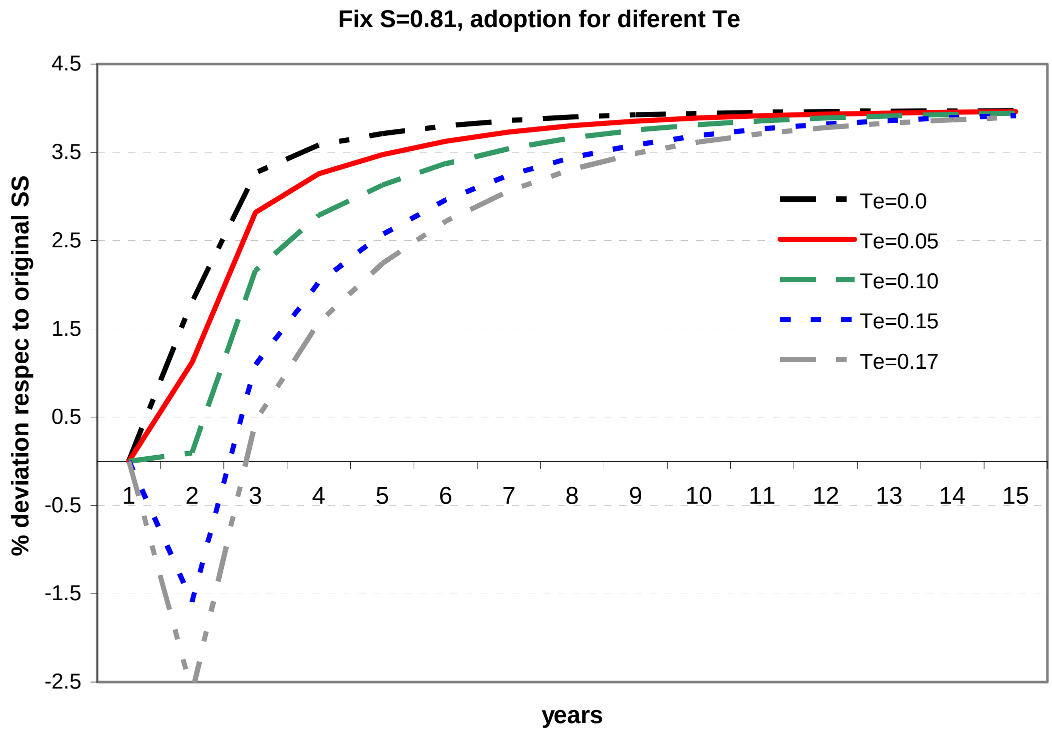


Figure 5

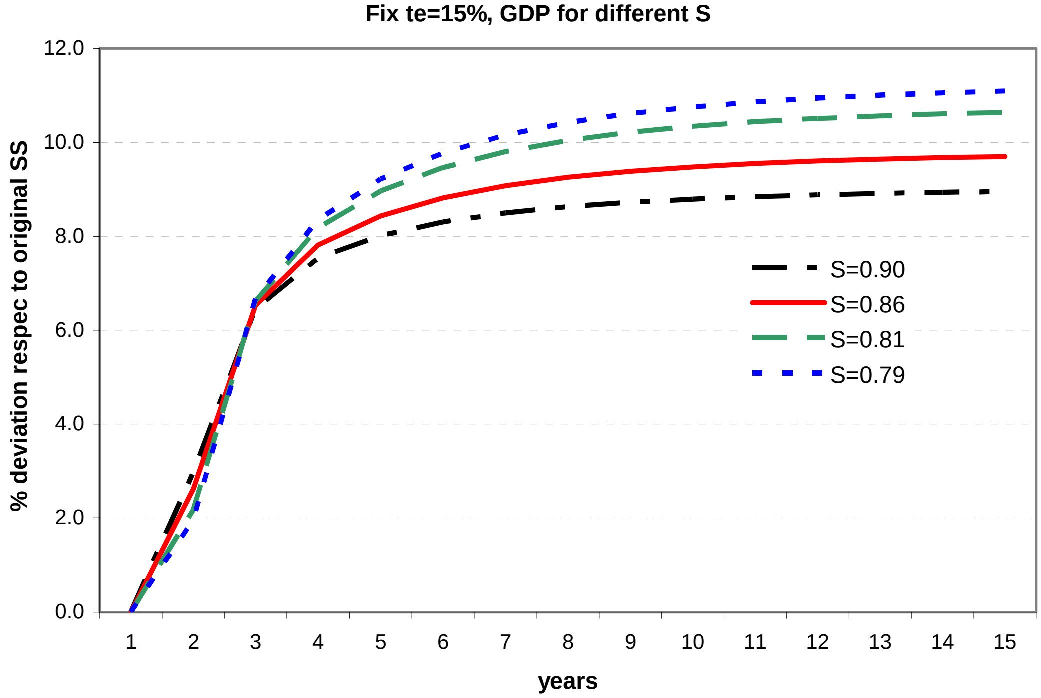


Figure 5 is simulation 4 proposed by Norman, each line assumes a different steady state value of S and the same entry tax set at 15%. Then, the economy is perturbed with a leading edge technology shock of 10% and simultaneously the entry tax is reduced to 10%.

Exercise: shock of 10% on leading edge technology. Then compare different economies with different steady state distortions. Efficient economy has no taxes. Other economies have no taxes except by one. All taxes are 10%. Example, Entry tax means all taxes zeros except by entry tax that is 10%.

Interpretation: each number is the percentage of the total jump that happens in that year. For example, is after a shock the steady state of the economy jumps 5% and in the first year the GDP jumps only 0.5%. Then 10% of the jump happens in period 1. Going further, if for the second year the economy is already 2.5% above the pre-shock situation, then 50% of the jump happens in the first two years, and so on. Those are the numbers is the table bellow

Percentage of total gain in output by year t

Year	Efficient	Entry tax	Exit tax	Entry and Exit
1	11.50	11.42	11.42	11.35
2	65.68	39.64	55.58	19.59
3	86.01	68.27	79.07	54.70
4	94.22	81.68	89.29	72.12
5	97.30	88.21	93.72	81.29
6	98.73	92.08	96.10	87.02
7	99.49	94.59	97.55	90.87
8	99.87	96.25	98.44	93.51
9	100.04	97.37	98.98	95.34
10	100.10	98.11	99.31	96.60

Next table is like the one above (shock on z of 10% and the same interpretation) but now there are two distortions at the same time. The entry tax is set at 10%, then we see what happens when there are different development barriers (s).

Percentage of total gain in output by year t

Year	S=0.9	S=0.86	S=0.81	S=0.77
1	27.26	16.10	2.37	-14.97
2	70.26	63.05	54.22	43.16
3	81.47	76.30	69.98	62.07
4	86.95	83.14	78.50	72.71
5	90.79	87.98	84.56	80.29
6	93.51	91.43	88.90	85.75
7	95.39	93.85	91.97	89.64
8	96.69	95.54	94.15	92.41
9	97.58	96.73	95.69	94.40
10	98.21	97.57	96.80	95.83

Same as the last (shock on z of 10% and the same interpretation) but now we set s=0.81 (10% below the efficient) and we see what happens when there are different entry taxes.

Percentage of the jump in year t

year	0%	5.00%	10%	15%
1	45.49	28.14	2.37	-40.01
2	82.00	70.77	54.22	27.37
3	89.92	81.83	69.98	50.85
4	93.16	87.21	78.50	64.51
5	95.38	90.98	84.56	74.27
6	96.90	93.65	88.90	81.31
7	97.91	95.49	91.97	86.35
8	98.56	96.76	94.15	89.97
9	98.98	97.64	95.69	92.58
10	99.25	98.25	96.80	94.47

The last exercise is explained in figure 5 that I sent before. Simulation 4 proposed by Norman, each case assumes a different steady state value of S and the same entry tax set at 15%. Then, the economy is perturbed with a leading edge technology shock of 10% and simultaneously the entry tax is reduced to 10%.

Percentage of the jump in year t

year	S=0.9	S=0.86	S=0.81	S=0.79
1	32.99	26.84	20.24	17.45
2	71.66	66.81	61.72	59.60
3	83.58	79.96	76.18	74.63
4	88.94	86.27	83.49	82.36
5	92.18	90.21	88.17	87.33
6	94.33	92.87	91.36	90.74
7	95.80	94.72	93.60	93.14
8	96.85	96.04	95.22	94.88
9	97.61	97.01	96.40	96.15
10	98.19	97.74	97.28	97.10

Table 1. Technological innovation

Method of estimation: Ordinary Least Squares with Robust Standard Errors

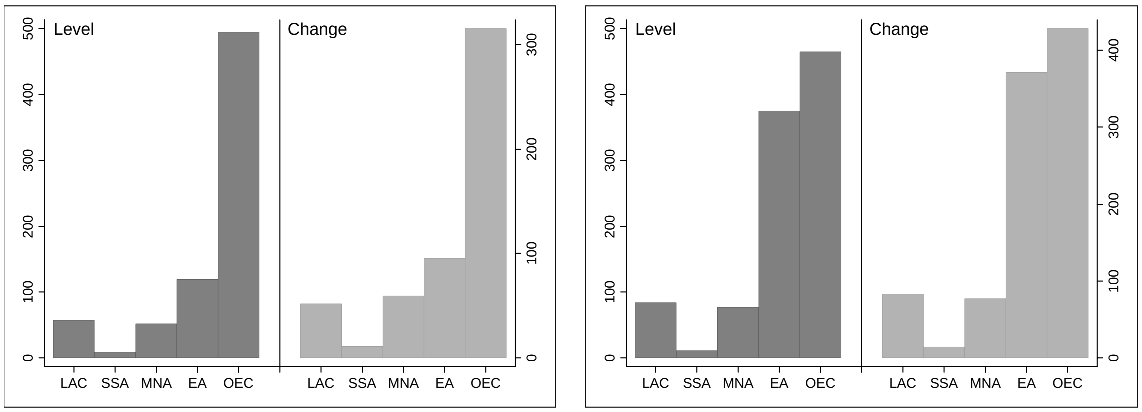
	Personal Computers (per 1,000 people)			Internet Users (per 1,000 people)		
Regulatory Freedom	25.48*	-132.01**	-67.26**	26.44**	-77.05**	-12.42
(index of Credit, Labor and Business Regulation, by The Fraser Institute: higher, less regulated; country average)	[1.97]	[3.09]	[2.25]	[2.06]	[2.66]	[0.51]
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.

Figure 1. Technological Innovation per World Region

Personal Computers (per 1,000 people) **Internet Users (per 1,000 people)**

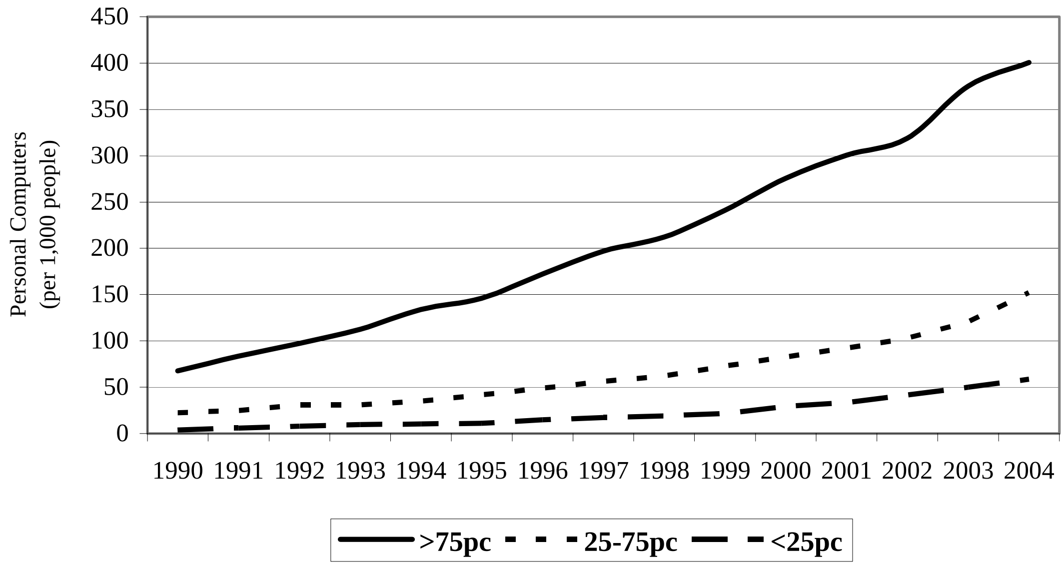


Notes:

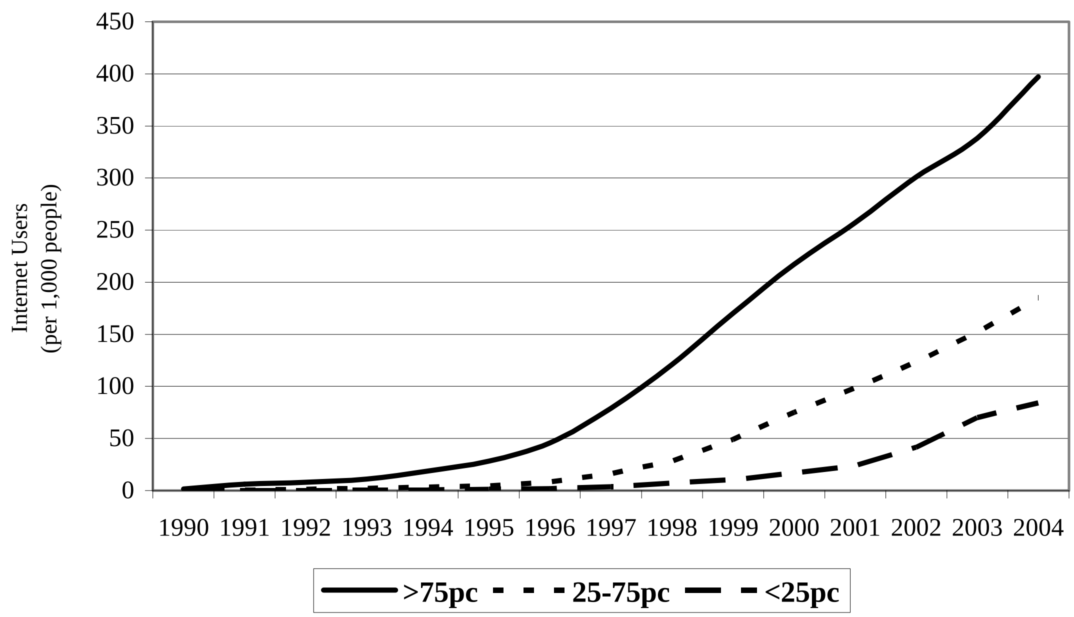
1. LAC: Latin America and the Caribbean; SSA: Sub-Saharan Africa; MNA: Middle East and North Africa; EA: ASEAN+2 (South Korea and China) excluding LICs; OEC: OECD.
2. Median value of each country group.
3. Level indicates an average of 2003-2004 by country, and change means the difference between the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

Figure 2. Technological Innovation and Regulatory Freedom

Personal Computers by Level of Regulatory Freedom

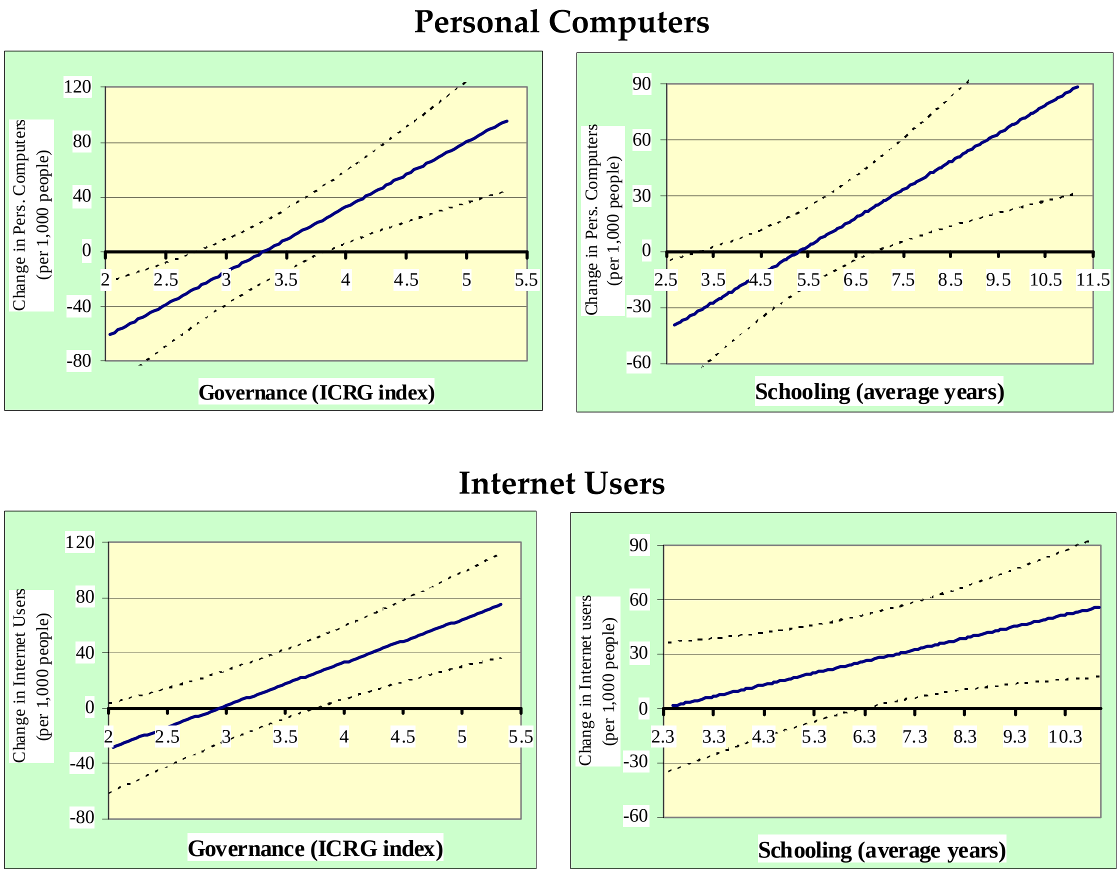


Internet Users by Level of Regulatory Freedom



Notes:
1. Lines shown represent average per group (top quarter, inter-quartile range, bottom quarter) according to Regulatory Freedom as of mid 1990s.
2. Data on Personal Computers and Internet Users are from World Development Indicators. Data on Regulatory Freedom are from the Fraser Institute.

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



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.

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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).