INSTITUTO DE ECONOMÍA

DOCUMENTO de TRABAJO

430

2013

Productivity Differences and the Stage of Development: Where are the Bottlenecks?

J. Rodrigo Fuentes; Verónica Mies.

www.economia.puc.cl • ISSN (edición impresa) 0716-7334 • ISSN (edición electrónica) 0717-7593

Productivity Differences and the Stage of Development: Where are the Bottlenecks?*

J. Rodrigo Fuentes (P. Universidad Católica de Chile)

Verónica Mies (P. Universidad Católica de Chile)

March 2013

Abstract

Adoption of better technologies is a crucial way for developing countries to close productivity gaps with leading economies. However, the possibility of growing through adoption depends decisively on the country's absorptive capacity. We build a theoretical model of technology adoption that focuses on four factors that shape the absorptive capacity of countries, namely: i) quantity of education; ii) quality provided by the education system; iii) microeconomic flexibility that favors the entry and exit of firms; and iv) the overall institutional environment that enhances/impedes R&D activities. We calibrate the model for a sample of 78 economies. The United States is our benchmark leading economy. We disentangle the relative weight of each development factor in explaining per capita income differences and study patterns in relationships between the type of development barrier and the level of development.

The effect on the steady-state gap of improving any of the aforementioned factors represents a trade-off between the initial gap and the value of the rest of the parameters. For instance, a relatively low level of market flexibility and quality of the education system are the main impediments that high-income economies face in closing the gap with the United States; the former explains almost forty percent of the gap for high-income countries, while the latter accounts for nearly twenty percent of this gap. A remarkable result is the small effect that individual reforms have on steady-state productivity in low-income countries. With the exception of R&D-favoring institutions, the remaining three factors are individually responsible for less than fifteen percent of the gap. This result is explained by a poor global economic environment that reduces the effect of each factor when implemented individually. In fact, there are significant nonlinearities between the level of development and the effects of individual reforms that are due to the strong complementarities between the different development factors. A high degree of development implies that the factors are at a high level, increasing the effects of particular reforms on steady-state productivity. However, it also reflects a small technology gap, which reduces their potential impact. The calibration shows that the effects are greatest for middle-income countries and lowest for low- and high-income countries.

Keywords: TFP, technological adoption, economic growth, development, income gaps, barriers, human capital. JEL Class: O1, O3, O4, O5

* We would like to thank participants at the North American Summer Meeting of the Econometric Society, EEA and LACEA meetings, Pontificia Universidad Católica de Chile and the Universidad de Chile seminars. Corresponding author email: vmies@uc.cl

1. Motivation

Persistent differences in the level of GDP per capita between countries and across periods remains one of the most important phenomena studied in development economics. Today the consensus is that disparities in total factor productivity (TFP) largely explain observed differences in long-run GDP per capita across countries (see, for instance, Klenow and Rodriguez-Clare, 1997; Parente and Prescott, 2002; Hall and Jones, 1999; Caselli, 2005). Based on this evidence, theoretical and empirical studies have focused on explaining TFP gaps between economies. One key factor that explains long-run productivity is technology and a crucial way for developing countries to improve technology is through adoption. When analyzing why economies fail to grow through adoption, we find that the following factors are most commonly studied in the literature: the poor quality of institutions that hinder adoption of and innovation in new technologies; microeconomic factors that induce misallocation of resources; scarcity of appropriate human capital to develop adoption; and innovation capacities.

Grounded in these four mechanisms stressed in the literature, this paper assesses the impact of four factors in closing the technology gap between any type of economy and a benchmark leading economy, specifically: market flexibility (rate of creative destruction), quality of institutions, quantity of human capital and quality of this human capital. This approach provides a comprehensive quantification of the different bottlenecks as it does not concentrate on just one channel, as many papers do, but jointly analyzes several development factors and their corresponding interactions.

Our first contribution is to propose a stylized model of technology adoption that encompasses all four factors. In our model, technology is the only factor affecting productivity; thus, we use both denominations indistinctively. The solution of the model provides the steady-state TFP gap of any economy with respect to a benchmarkcountry. We calibrate the steady-state gap and quantify the impact of each of the factors in explaining this gap. We also relate these impacts to the stage of development of the economies.

The second contribution of this paper is related to two connected questions. First, why do similar reforms have different impacts in economies with different levels of development? Second, to what extent does a particular sequence of reforms affect the impact of each one on TFP gaps? The model produces interactions that enable us to understand the type and degree of complementarities that affect the final impact of a (sequence of) reform(s). In particular, the impact of a reform depends on the level of development through two opposing effects. On the one hand, the lower the level of development, the longer the distance to the technological frontier and thus the higher the gains of implementing any reform. The reason is that potential growth through adoption is increasing in the technology gap. But, on the other hand, the lower the level of development, the poorer the absorptive capacity. This poor absorptive capacity diminishes the impact of any particular reform. These two forces are considered when analyzing the effectiveness of policies aimed at closing the gap.

The third contribution is the analysis of the level of per capita income of seventy-eight economies at different stages of development. We divide the countries into four income groups and discuss whether there is a pecking order in the way that economies improve factors on the path of development. Different bottlenecks, gains and interactions occur in different development stages.

There is a large body of literature focused on how technology adoption explains cross-country differences in TFP and thus per capita GDP. The mechanism is basically the following: All economies face the same global pool of technologies. However, each country has a different absorptive capacity that determines its TFP gap in steady state. This absorptive capacity is usually limited by barriers that hamper the full use of more efficient technologies (e.g., Parente and Prescott, 1999); distortive policies that produce misallocation of resources (e.g., Banerjee and Duflo, 2005; Lagos, 2006; Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009; Bartelsman, Haltiwanger and Scarpetta, 2012); inadequate human capital that obstructs the implementation of adopted technology (e.g., Nelson and Phelps, 1966; Benhabib and Spiegel, 2002; Acemoglu and Zilibotti, 2001) and institutions that are unfriendly to the adoption activity (Acemoglu, 2009; Parente and Prescott, 1994, among others). In a related type of papers, Comin and Hobijn (2004) study the diffusion of 20 technologies in 23 countries and associate the rate of adoption to factors such as openness, human capital and the economic regime of the countries under study. In a complementary view, Córdoba and Ripoli (2008) show that most cross-country differences in output per worker are explained by barriers to the accumulation of factors that are rival (physical and human capital) and to a lesser extent by barriers to the accumulation of knowledge. Our paper takes both kind of factors into account and distinguishes which types of factors are more relevant in a given stage of development.

We develop a model of endogenous technological change through adoption. Based on Howitt (2000), we consider three sectors. The first is a perfectly competitive sector, which produces the final good using labor and a set of differentiated intermediate inputs. The productivity of each input depends on a technology parameter that is specific to that input. Each intermediate good is produced by a monopoly (the second sector) that uses only capital as input. All the action of the model takes place in the third industry, the research and development (R&D) sector, where a continuum of firms invests in R&D to adopt the best technology available and become the new monopolies. At the world level, there is a technological frontier that grows at a constant rate. R&D is a risky activity, implying that in each period only a fraction of these firms succeeds in adopting a better technology. At the aggregate level, however, there is no uncertainty and technological change depends only on the absorptive capacity of the economy and the gap between the average technology of the country and the technological frontier.

We calibrate the implied steady-state GDP per worker for the countries in our sample. The model closely resembles the distribution of GDP per worker in our sample, which enables us to conduct some policy experiments. We divide the sample of countries into four income groups: high-, upper-middle-, lower-middle- and low-income. For each income group we construct the steady state of a synthetic country using the median value of each parameter over the country group. Our benchmark leading economy is the United States.

Using the solution of the model for the steady-state technology gap with respect to the leading economy, we conduct two exercises for each synthetic economy. First, starting from the actual steady-state gap we improve one parameter at a time to the level of the United States and compute how much of the gap is closed by this improvement. Second, starting from the level of the United States, we reduce the value of each parameter to the level of the synthetic country and compute how much the gap increases due to the worsening of the parameter. The impact of each change depends on the distance to the frontier and the overall economic environment of the economy.

The results show different bottlenecks for each type of economy. The final effect of each factor is highly nonlinear, emphasizing the importance of the underlying interactions among parameters that determine the absorptive capacity of the economy. For instance, low-income countries with poor overall economic environment (poor institutional quality, low creative destruction rate and low levels of quality and quantity of human capital) require "big bang"-type reforms. Despite the long distance to the technological frontier, the effects of individual reforms are minimized by the low level of all the other factors. The only exception is institutions, which shows the highest effect for low-income economies.[1] High-income countries also show low returns from individual factors despite benefitting from a good overall environment. The reason, in this case, is that they are already positioned close to the technological frontier and thus there is less to be gained. In contrast, upper-middle- and lower-middle-income economies exhibit significant effects from individual reforms because the economic environment is reasonably positive and there is a large potential for growth through catching up.

In relative terms, high-income and upper-middle-income economies face the challenges of raising the rate of entry and exit of firms, which we associate with market flexibility, and improving the quality of human capital. Lower-middle-income and low-income countries should advance in improving institutions that favor the R&D activity.

[1] In this paper, we only consider the effects on productivity of a certain reform; we do not consider the cost of introducing that particular reform.

From our analysis, we conclude that countries tend to improve institutions first, followed by an increase in years of schooling. These two significant reforms usually enable poor countries to become middle-income countries. In this new stage of development economies put efforts into increasing, to some extent, the quality of education and introduce some market flexibility, but postpone a full reform in these areas to later stages of development. We find that what distinguishes a low-income economy from a middle-income economy is the quality of its institutions. However, after institutional improvement, the second most effective reform is an improvement in the quality of education. However, the benefits of this reform tend to take a longer time to become apparent.

The paper is organized as follows. Section 2 presents a model of technology adoption. In sections 3 and 4 we calibrate the model for a wide sample of seventy-eight economies and perform different exercises to evaluate the fit of our model. Section 5 discusses the different bottlenecks associated with each development stage. In this section, we analyze in detail the interactions implied by the analytical framework. Finally, Section 6 presents some concluding remarks.

2. The analytical model

The model builds upon Howitt (2000). Assume that there are J small open economies in the world. Each economy trades only the final consumption good and is open to capital flows. Each economy is composed of three sectors: A homogeneous and competitive final goods sector, an intermediate sector producing inputs of different quality, and an R&D sector. The intermediate sector comprises a continuum of monopolies producing productive inputs. In the R&D sector, R&D firms make risky investments to improve the technologies embedded in the intermediate input through technology adoption. Successful R&D firms copy the technological frontier and become the new monopolies. The technological frontier grows exogenously at the world level at the constant rate g.

Each economy is inhabited by a continuum of identical households that live infinitely. Households derive utility only from the consumption of the final good and inelastically supply their endowment of labor. There is no population growth. We further assume that markets are complete and that there is perfect access to the foreign capital market. In this framework the risk exists at the level of the firm, but it is completely diversified; thus there is no aggregate risk. In this setting, consumption and production decisions are independent. Optimal financial wealth allocation, in contrast, implies some arbitrage conditions that are used to derive certain equilibrium relations. The complete development path of an economy can be characterized by studying the production and R&D decisions and by exploiting the mentioned arbitrage conditions. We start by presenting the firms' problem in the final and intermediate production sectors.

2.1 Producers

Consider the economic structure of one benchmark country j. The final goods sector is competitive. The representative firm in this sector produces a perishable good Y_t using labor flows L and inputs x_{it} according to $Y_t = L^{1-\propto} \int_0^1 A_{it} x_{it}^{\propto}\, di$. Input i embeds a productivity level of A_{it}. The higher the productivity embedded in input x_{it}, the higher the quantity of final good that one unit of x_{it} generates. Given the price of intermediate input p_{it}, the demand for input x_{it} corresponds to

$$x_{it} = \underset{x_{it}}{argmax} \left(PL^{1-\propto} \int_0^1 (A_{it} x_{it}^{\propto} - p_{it} x_{it})\, di - wL \right).$$

The intermediate sector comprises monopolies producing intermediate inputs. Inputs differ in the productivity that they provide. Input i is produced with the following technology: $x_{it} = K_{it} / A_{it}$, implying that physical capital requirements to produce one unit of x_{it} depend on the technology level embedded in x_{it}. The higher A_{it}, the more physical capital is needed to embed this technology in x_{it}. Firm i sells input i to the final goods firm at the monopoly price p_{it} and for the use of capital, pays its competitive rental price r_t. Given the maximization problem, the R&D firm optimally chooses the amount $x_{it} = L\left(\alpha^2 / r\right)^{1/(1-\alpha)}$, which only depends on two aggregate variables: the rental price of capital and the total flow of labor. Therefore, every sector supplies an equal amount of inputs. Perfect access to the foreign capital market ensures that in equilibrium $r_t = r^*$, where r^* is the world steady-state interest rate. Optimal x_{it} is independent of the level of technology embedded in the input because the costs and benefits are proportional to the technology. Monopolists' profits, in contrast, depend on the technology embedded in input x_{it} and correspond to $A_{it}\pi_t$, where $\pi_t \equiv \alpha(1-\alpha)(\alpha^2 / r)^{\alpha/(1-\alpha)} L$. The flow π_t is equal across sectors as it depends only on aggregate variables and is constant over time. Differences in monopolists' profits are solely explained by differences in the productivity provided by the input.

2.2 The R&D market

The R&D sector comprises R&D firms intending to become new monopolies. These firms make risky investments to improve the current technology in use in sector i. If the firm succeeds, it becomes the new monopoly and starts producing with the better technology. The previous monopoly stops producing and begins to engage in R&D activities.

The R&D firm chooses the amount to invest in R&D, I_{it}, by considering R&D profits and expenses. There is no aggregate risk and firms maximize the expected net benefit from R&D as in equation (1).

$$\max_{I_{it}} \left(\beta I_{it} / \bar{A}_{it}\right) W_{it} - I_{it}(1+\tau) \qquad (1)$$

We assume that investment in R&D only affects the probability of success[2] defined as βn_{it}, where $n_{it} \equiv I_{it} / \bar{A}_{it}$ and β corresponds to the productivity of R&D. $\bar{A}_{it}$ is the

[2] Assuming that R&D investment affects only the probability of success and not the technology improvement simplifies the discussion of the mechanisms and makes the model more tractable. The cost of this is that the framework does not allow for analyzing how resources invested affect the technology improvement in a particular sector. However, at the aggregate level, resources invested affect the average technology improvement of the economy (in Section 4 we discuss the implications for aggregate relationships).

level of technology that a successful R&D firm achieves and is constant for the whole period in which the firm remains as the monopoly. W_{it} denotes the present value of the expected cash flows conditional on success, where $W_{it} = \frac{1}{1+r}\overline{A}_{it}\pi_t \sum_{t+1}^{\infty}\left(\frac{1-\phi_s}{1+r}\right)^{s-t-1}$ and ϕ_t correspond to the probability that the monopoly will be displaced by a successful R&D firm in the future. The cost of R&D is given by the amount of R&D invested, I_{it}, adjusted by all subsidies/taxes imposed on the R&D activity comprised in a sole parameter τ. The problem's first order condition states that:

$$\beta \frac{W_{it}}{\overline{A}_{it}} = (1+\tau) \qquad (2)$$

As this first order condition is valid in every period t, the ratio $W_{it} \;/\; \overline{A}_{it}$ is constant in every period. The latter implies that the displacement rate ϕ_t has to be constant too; this comes from the definition of W_{it} :

$$W_{it} = \overline{A}_{it}\ \frac{\pi}{r+\phi} \qquad (3)$$

We solve for the symmetric equilibrium in which the displacement rate ϕ (probability of success of outside firms) is equal to the probability of success of R&D firms, $n\beta$. Combining equations (2) and (3), we derive the rate of entry and exit in equilibrium, which corresponds to

$$\left(I_{it} / \overline{A}_{it}\right)\beta = n\beta = \beta\pi/(1+\tau) - r \qquad (4)$$.[3]

The rate of entry and exit, $n\beta$, is key for our empirical exercise. This rate depends positively on expected profits π and R&D productivity β and negatively on taxes and the cost of capital. In a broader sense, this rate depends on all regulations, taxes, and subsidies that affect the entry and exit of firms and is associated with microeconomic

[3] Consequently, the equilibrium R&D investment is $I_{it} = \overline{A}_{it}\left(\pi/(1+\tau) - r/\beta\right)$.

conditions of the economy.

2.3 The technology improvement $\overline{A}_{it}$ and the aggregate equilibrium

All optimal relationships in the previous sections are independent of the potential technology improvement $\overline{A}_{it}$. The reason is that all costs and benefits are proportional to the potential technology level. Therefore we can treat the technology improvement separately from the problems previously analyzed. We turn now to the discussion of $\overline{A}_{it}$. We assume that R&D comprises only adoption activities, which correspond to the copy of existing technologies. If the R&D firm succeeds, it attains the target technology $\overline{A}_{it}$, which fulfills two conditions:

i. $A_{it-1} < \overline{A}_{it} < A_{\max t-1}$

ii. $\overline{A}_{it} - A_{it-1} = \Gamma(H,\lambda)\,(A_{\max t-1} - A_{it-1})$

First, the target cannot be larger than the technological frontier (equation i). Second, following the idea of Nelson and Phelps (1965), further extended by Benhabib and Spiegel (2002), we assume that the country's absorptive capacity Γ (H, λ) depends on the stock of human capital (H) and the institutions that favor/hinder the adoption of technologies, λ. Specifically, we define the absorption capacity as $\lambda\left(H_{t-1}/H^{*}_{t-1}\right)^{\gamma}$ and the technology improvement by a successful R&D firm as:

$$\overline{A}_{it} - A_{it-1} = \lambda\,(H_{t-1}/H^{*}_{t-1})^{\gamma}\left(A_{\max t-1} - A_{it-1}\right) \quad ;\gamma \geq 0 \quad ;\lambda \in [0,1] \qquad (5)$$

Parameter λ comprises all institutional effects such as policies, institutions, or incentives to copy foreign technologies, reflecting the kinds of barriers emphasized by Parente and Prescott (1994).[4] It fluctuates in the range $[0,1]$. No barriers to adopting new

[4]For example, access to the internet and to communication systems, economic and legal regulations, adoption-related policies (e.g., opportunities to attend seminars and congresses) and all variables that affect the overall efficiency of the adoption activity.

technologies implies a value of λ equal to one and, conversely, maximum barriers imply that $\lambda = 0$. The value of this parameter varies across countries.

The term $(H_{t-1} / H^{*}_{t-1})^{\gamma}$ accounts for the role of human capital in enabling the implementation of the adopted technology.[5] H_t is a measure of the stock of human capital per worker. Adopting a new technology is not an automatic process in the sense that it requires human capital to be implemented. We assume further that the relevant stock of human capital not only depends on the absolute human capital stock, but on the complexity of the targeted technology, which we assume is the technological frontier. This assumption is in line with the literature on appropriate technology, which states that technologies produced in advanced economies are developed for the mix of inputs of those economies. As a result, developing economies copy only imperfectly these technologies as they have a different mix of inputs (e.g., Acemoglu and Zilibotti, 2001). As a proxy for the human capital needed to fully copy this technology, we use the stock of human capital of the countries that are systematically shifting the technological frontier. This stock is denoted by the variable H^* and corresponds to the per-worker stock of human capital of the stand-in leading economy. Parameter γ denotes the intensity with which the human capital component is used in the adoption activity. This parameter is equal for all countries. A value of γ=0 implies that human capital is not needed as an input for adoption and consequently does not affect the adoption possibilities of the country. As the value for this intensity increases, human capital as an input for adoption becomes more relevant.

Now, from the aggregation of each sector's result, we obtain the law of motion of the average productivity A_t for every country *j* as presented in equation (6). Recall that at the aggregate level, a fraction $n_j \beta_j$ of R&D firms is successful in every period.

[5]Benhabib and Spiegel (2002) establish in what they call a logistic form of technology diffusion that the technological improvement depends on the technology gap and the level of human capital. In our model, human capital requirements are associated with the human capital stock needed to copy a certain technology.

$$A_{t,j} = A_{t-1,j} + n_j \beta_j \left[\lambda_j \left(H_{t-1,j} / H^*_{t-1} \right)^{\gamma} \left(A_{\max t-1} - A_{jt-1} \right) \right] \quad j = 1,2,3..J \qquad (6)$$

As we focus on the steady-state properties of the model, we assume that the stock of human capital is constant, but the level is heterogeneous at the country level. In line with Hall and Jones (1999) we proxy the stock of human capital as the return to schooling (1+*q*) raised to the power of the years of schooling (κ) of the representative agent as in the following equation: $H_j = \left(1 + q_j\right)^{\kappa_j}$.

2.4 The steady state

We assume that the technological frontier grows at a constant rate *g*. Dividing equation (5) by $A_{max\ t-1}$ and solving for the stationary ratio, we find the steady-state technology gap with respect to the technology frontier for country *j*:

$$a_{ss,j} \equiv \frac{A_{t,j}}{A_{\max t}} = \frac{n_j \beta_j \lambda_j \left(H_j / H^* \right)^{\gamma}}{\left[g + n_j \beta_j \lambda_j \left(H_j / H^* \right)^{\gamma} \right]} \quad j = 1,2,3..J \qquad (7)$$

The steady state gap between the actual level of technology and the frontier depends negatively on the domestic rate of entry and exit of firms, represented by *nβ*, the quality of institution λ and the relative level of human capital. Besides, the larger the required intensity in human capital to adopt better technologies γ, the larger the steady-state gap will be. Finally, the faster the technological frontier grows (the larger g is), the larger the steady-state gap will be, everything else constant.

The leading economy (denoted by a star), on the other hand, presents the following solution: $a^*_{ss} = A^*_t / A_{\max t} = n^* \beta^* \lambda^* / \left(g + n^* \beta^* \lambda^* \right)$, so that the ratio between economy *j* and the stand-in leading economy is given by:

$$\frac{a_{ss,j}}{a^*_{ss}} = \frac{n_j \beta_j \lambda_j \left(H_j / H^* \right)^{\gamma}}{n^* \beta^* \lambda^*} \frac{\left[g + n^* \beta^* \lambda^* \right]}{\left[g + n_j \beta_j \lambda_j \left(H_j / H^* \right)^{\gamma} \right]}$$

This ratio is also increasing with the rate of entry and exit of firms, the relative stock of human capital of the economy, and the quality of the institutions. The effect of the growth rate of the technological frontier, *g*, is ambiguous. If the leading economy has a higher absorptive capacity than country *j*, then an increase in *g* enlarges the TFP gap in steady state between the non-leading and the leading country. The contrary happens if the leading economy has worse parameters.

3. Empirical evaluation

The theoretical model proposes four factors for explaining productivity and per-worker income gaps, specifically: the institutional environment that favors the adoption activity, the quantity of education received by the workforce, the quality of the education system, and the entry and exit of firms.

The two goals of this section are to disentangle the relative weight of each development factor in explaining per-worker income differences and to study whether there are any patterns in the relationship between the type of development barrier and the level of development. To accomplish these tasks, we first calibrate relative steady-state productivities (equation 4) for a large sample of economies and perform tests to analyze whether there is a reasonable fit of the data. Afterwards, we classify each economy in one of four income groups: low-income, lower-middle-income, upper-middle-income and high-income. Then, we perform different exercises to measure the relative weight of each development barrier in each type of income group to finally discuss some implications for the development process.

3.1 Data and parameters

We construct a sample of seventy-eight countries, based solely on data availability as the selection criterion. We classify each country according to its income level. We have nineteen high-income countries (HIC); twenty-seven upper-middle income countries (UMIC); twenty-one lower-middle-income countries (LMIC); and eleven low-income countries (LIC). Table A1 in the appendix lists the countries in the sample. All policy parameters are country-specific. Table A2 presents the values for all parameters for each economy.

The institutional parameter λ corresponds to the entire institutional framework that enhances or impedes the transfer and copy of new technologies. We calibrate it using the Knowledge Economy Index (KEI) related to the country's innovation capacity. The World Bank has constructed various KEI indicators that measure the capacity of an economy to diffuse and produce knowledge[6].

The entry and exit rate is an endogenous variable that depends on R&D taxes and subsidies, R&D productivity, parameters of the production function and the real interest rate. Therefore, imposing a shock on the other parameters (education quality, years of schooling, R&D-related institutions) will not affect the entry/exit rate. Moreover, every shock to the entry and exit rate can be related to a shock to any of its underlying determinants. We use the entry rate of firms reported by the World Bank for 2005 or the data available as of the nearest date. In the set of robustness exercises, we also calibrate this variable, averaging the entry and exit rates of firms for the period 2000-2005.

In the analytical model, the stock of human capital is constant but shows heterogeneity across countries. For our calibration, we assume that this stock corresponds to the interaction of two variables: quantity and quality of education. For quantity of education, we use the average years of schooling (κ_j) as reported by Barro and Lee (2010) and for quality of the education system, we seek a measure that allows for comparing systems across countries. Therefore, we use the marginal return of an additional year of education of an immigrant in the United States (q_j) as estimated by Schoellman (2012).

[6] Quoting the definition provided by the World Bank, the Knowledge Economy Index takes into account whether the environment is conducive for effective use of knowledge for economic development. It is an aggregate index that represents the overall level of development of a country or region towards the knowledge economy. The KEI is based on the average of the normalized performance scores of a country or region on all four pillars related to the knowledge economy: economic incentive and institutional regime, human resources, the innovation system and ICT.

The measure of this return in the United States cleans to some extent the effect of country-specific factors on schooling returns as a proxy for the quality of the educative system.[7]

The following tables present the median parameters and the corresponding standard deviations for the countries by income group. Table 1a shows the median parameters across groups. The last two columns show the median GDP per worker relative to the United States and the absolute median GDP per worker. The last row shows the corresponding values for the United States. Table 1b presents the corresponding standard deviations.

Table 1a: Country group parameters, median values

Median	Years	Quality	Flexibility	Institutions	GDPWR[(1)]	GDPW[(2)]
HIC	10.784	0.079	0.096	0.952	0.753	52,182
UMIC	9.053	0.049	0.079	0.652	0.268	18,566
LMIC	8.308	0.049	0.080	0.377	0.131	9,104
LIC	5.370	0.028	0.066	0.230	0.050	3,475
USA	12.201	0.093	0.129	1.000	1.000	69,318

[(1)] GDP per worker with respect to the United States. (2) GDP per worker PPP.

Sources: Authors´ calculations based on data from the World Bank, the International Monetary Fund, Barro and Lee (2010) and Schoellman (2012).

Table 1b: Country group parameters, standard deviations

St. Dev.	Years	Quality	Flexibility	Institutions	GDPWR[(1)]	GDPW[(2)]
HIC	0.965	0.024	0.028	0.109	0.116	8,020
UMIC	1.801	0.022	0.023	0.151	0.103	7,148
LMIC	1.801	0.022	0.020	0.108	0.036	22,581
LIC	1.280	0.036	0.023	0.086	0.012	839

[(1)] GDP per worker with respect to the United States. [(2)] GDP per worker PPP.

Sources: Authors´ calculations based on data from the World Bank, the International Monetary Fund, Barro and Lee (2010) and Schoellman (2012).

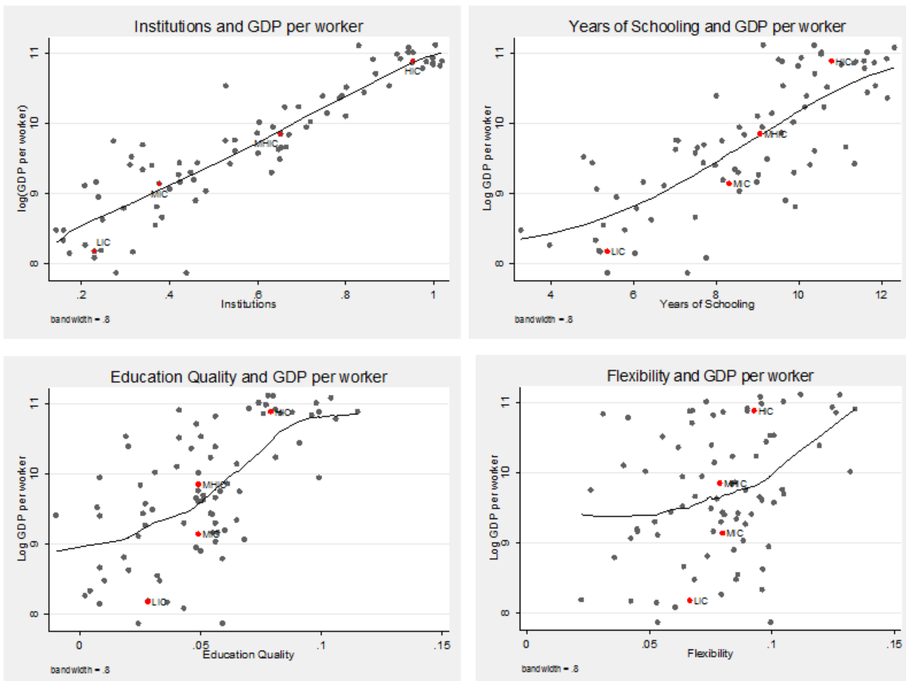
[7] The author performs different exercises to show that his results are not driven by selection. As a robustness check, we also use international test scores as a proxy for the quality of the education system. These exercises may be obtained from the author upon request.

As expected, the value of almost all parameters increases with the level of development proxied by per worker GDP. However, there are some interesting features worth mentioning. Upper-middle-income countries and lower-middle-income countries show similar values for the quality of the education system and the flexibility of their markets. Moreover, median years of schooling are not significantly different between these two groups, suggesting that the discriminating factor between both groups is the institutional environment favoring the adoption/creation of new technologies. One hypothesis is that improving the institutional environment is relatively easier than the other parameters. Another hypothesis is that the improvement of institutions produces a significant improvement in overall economic conditions that allows countries to move into the upper-middle-income group. Finally, flexibility of markets and quality of education show relatively large dispersions.

Figure 1 shows the relationship between each development factor and income per worker. The red dots correspond to the median parameter for each group. This is a characterization of each income group by the determinants of absorptive capacity; it is not an attempt to find causality among these variables.

All factors are positively correlated with GDP per worker. However, this relationship is stronger for the quality of institutions and years of schooling than for quality of education and flexibility. This is especially true when considering the values and medians for the two middle-income groups. In addition, while institutions and years of schooling show an almost linear relationship with the level of development, the other two factors increase more at higher levels of development. There are various hypotheses that could explain this pattern: For example, one hypothesis is that the latter two reforms are costlier and more difficult to implement. Another example is that the political game impedes the implementation of certain types of reforms (Parente and Prescott, 1999).

Figure 1. Relationship between stage of development and determinants of absorptive capacity (1)



(1). Estimations correspond to locally weighted scatterplot smoothing.

Source: Authors´ calculations based on the World Bank, International Monetary Fund, Barro and Lee (2010), Schoellman (2012).

4. Calibration

In this section we calibrate the parameters for each country in the sample and obtain their corresponding relative steady-state TFP values (denoted by *a)*. The analytical model generates the neoclassical representation of the aggregate production function, $Y = K^{\alpha}(AL)^{1-\alpha}$, with constant returns to scale in capital and labor. We assume that capital and labor shares are equal across countries. We assign a value of 0.35 to the capital share of output α (Gollin, 2002) and 2.2 percent to the growth rate of the technological frontier, which corresponds to the average per-capita growth rate of the United States in the years 1960-2006.[8] Finally, we need an estimate of parameter γ. This parameter defines how intensively the adoption activity uses human capital to copy new technologies. As there is no previous reference for the value of this parameter, we solve the model with gammas between zero and two and evaluate the fit of the implied distribution of per worker GDP with the actual data distribution as provided by the World Bank for 2005. We first find the range of gammas that produce distributions that do not reject the hypothesis that actual and calibrated data come from the same distribution, according to the Kolmogorov-Smirnov test. Second, within that range, we choose the gamma that maximizes the p-value of the test. To construct the implied GDP per worker, we rewrite per-capita income ratios in the following way[9]:

$$\frac{y_i}{y_{US}} = \left(\frac{A_i}{A_{US}}\right)\left(\frac{K_i / Y_i}{K_{US} / Y_{US}}\right)^{\frac{\alpha}{1-\alpha}}, \quad \text{where} \quad y \equiv \frac{Y}{L} = A\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}}.$$

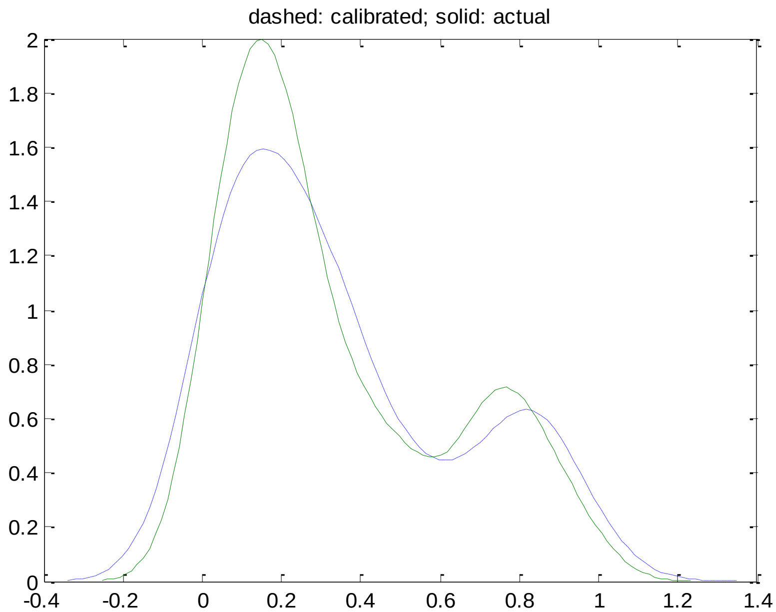
We take the TFP level of the United States as a proxy for the technological frontier. The chosen value corresponds to a gamma equal to 1.55.

Figure 2 shows the calibrated and the actual distribution of GDP per worker for the countries in the sample for 2005.

[8] Calculation based on Maddison (2009). The averages for the periods 1820-2006, 1900-2006 and 1960-2006 correspond to 1.84%, 2.08% and 2.21%, respectively. We choose the latter value as the U.S. has shown a relatively constant GDP growth rate in this period.

[9] The capital stocks were constructed using the perpetual-inventory method with data from the Penn World Table.

Figure 2: Calibrated and actual data, GDP per worker



Source: Authors' calculations.

The four factors that we identify as key variables in determining the absorption capacity of the economies explain a large fraction of the TFP gaps across economies. The natural question that follows is which factor(s) matters most for development.

5. Disentangling TFP gaps

This section is motivated by three related issues, namely: identifying the most binding factors for closing existing per-capita GDP gaps between different types of countries and the leading economy; finding the patterns, if any, in the relationships between each bottleneck and the level of development; and determining why the same reform can have different effects on productivity, depending on the stage of development. To accomplish these tasks we proceed in two steps: i) for each income group, we build a synthetic economy using the median value of the parameters of the factors described in 1a. Each synthetic country is then used to make some policy experiments to measure the contribution of each parameter to closing the TFP gap between that type of economy and the leading economy; ii) we explore the complementarities and interactions among the components of absorptive capacity in the development process[10].

The benchmark leading economy is the United States. We are interested in the relative steady-state TFP between the prototype economy and the United States; thus, a value of one denotes that the country reaches the same TFP level as the United States in steady state. This is equivalent to saying that the TFP gap with the United States is zero in steady state.

5.1 Bottom up and top down

We conduct two exercises. The bottom-up exercise starts with calibration of the steady-state technology gap with the United States using the current value of the parameters of the economies. Then, we quantify the effect of improving each parameter to the level of the United States while maintaining the rest of the parameters at their actual levels.[11]

The top-down exercise assumes that each synthetic country shares the parameters of the United States. As a consequence, there is no technology gap between any country and the United States in steady state (but there is a gap between the United States' average technological level and the technological frontier A_{max}). Afterwards, we evaluate the impact on TFP of returning one parameter at a time of the synthetic economy to its actual

[10] As a robustness check we repeat the same procedure for each economy and weigh them to produce an average contribution of each development factor. The results are very similar and are available upon request from the authors.

[11] As we stated in Section 2, the entry and exit rate is an endogenous variable that depends on R&D taxes and subsidies or R&D productivity. Therefore, imposing a shock on the other parameters (education quality, years of schooling, R&D-related institutions) will not affect the entry/exit rate. Moreover, every shock to the underlying factors of the entry and exit rate can be transformed into a shock to the entry and exit rate.

level. This allows us to determine the contribution of each parameter to explaining the gap. The effect of returning all four parameters to their actual levels generates the calibrated TFP gap.

Both exercises produce different results regarding the effect of a specific policy reform on the productivity gap, and these differences are explained by the different values of the interactions in each exercise. The next two tables present the results for the bottom-up measure. Table 2a shows the absolute contribution to closure of the gap while Table 2b presents the fraction of each gap that is closed by each development factor. Each column measures the effect of the corresponding factor in closing the gap. The values in the "interactions" column are calculated by subtracting the sum of all individual effects from the value of the calibrated gap. A priori the sign of this value is ambiguous. In the next section, we will discuss this effect in detail. The last column shows the steady-state gap when the parameters remain at their current values.

Table 2. Contribution to closure of the gap, by development factor and by country group: bottom-up measure

	a. Relative contribution					
	Years	Quality	Flexibility	Institutions	Interactions	Gap
	(1)	(2)	(3)	(4)	(5)	(6)
HIC	0.036	0.045	0.063	0.011	-0.016	0.139
UMIC	0.066	0.162	0.143	0.125	-0.041	0.454
LMIC	0.075	0.142	0.131	0.276	-0.008	0.617
LIC	0.045	0.045	0.085	0.120	0.327	0.252

	b. Relative contribution					
	Years	Quality	Flexibility	Institutions	Interactions	Gap
	(1)	(2)	(3)	(4)	(5)	(6)
HIC	0.208	0.265	0.370	0.065	0.092	1.000
UMIC	0.123	0.301	0.267	0.232	0.077	1.000
LMIC	0.119	0.224	0.208	0.437	0.012	1.000
LIC	0.055	0.103	0.144	0.394	0.304	1.000

Source: Authors' calculations.

As expected, the effect of improving any particular factor tends to decrease with the stage of development, although certain non-linearities appear. For instance, the effect of institutions monotonically decreases with the level of income per capita; on the other hand, benefits from improving the quality of education increase as the economy transits from the lower-middle-income group to the upper-middle-income group. Nevertheless, the impact of all factors on the productivity gap is smaller for the high-income group. This is because this group has a small gap with the leading economy, as shown in column 6, despite having high levels in the other factors that amplify the effects of any single reform.

Analysis of the factors' relative contribution to explaining the productivity gap (Table 2b) suggests that lack of market flexibility and poor education quality remain the most significant bottlenecks throughout the entire development path. In the case of high-income countries, lower flexibility with respect to the United States explains almost 40% of this group's gap while lower quality of the education system accounts for almost one-fourth of the gap. Moreover, these two factors seem to be the key to breaking the "curse" of middle-income countries. A not-so-obvious result, at first glance, is the scarce effect of each factor in explaining the gap between the low-income group and the leading economies. With the exception of the institutional environment, the other three factors explain individually less than 15 percent of the gap. This result is due to a globally poor economic environment that reduces the effect of each factor. This is comprised of the *Interactions* variable, which in this specific case accounts for the complementarities existing between the different factors. In the case of low-income countries, this complementarity effect explains 30% of the gap. Low-income countries thus face a challenge in improving reforms simultaneously. However, if just one reform were possible, improving institutions would have the most substantial effect.

Note that the importance of interactions decreases in relative terms as the level of development increases and becomes negative for countries with a medium level of development (Table 2b, column 5). The negative sign implies that the total effect of performing all the reforms simultaneously is less than the sum of each reform individually, because implementing one reform has a greater effect. This happens because the large productivity gap dominates the effect of having poor parameters. In contrast, when all reforms are implemented simultaneously, the level of absorptive capacity increases, but the productivity gap declines too quickly, reducing the overall effect.

Table 3 exhibits the result for the top-down calibration. In this exercise all countries share the same parameters as the United States, so that they all start at the same steady state. We then reduce the value of each parameter, one at a time, to the level of the synthetic economy and measure each factor's contribution to the gap. The results are qualitatively similar to the bottom-up exercise: Institutions are more important for low-income countries and flexibility is the bottleneck for high-income economies. One difference is the role played by the quality of education, which becomes highly important from the very early stages of development and, as in the previous exercise, continues to be important in explaining the curse of middle-income countries.

A second difference is that interactions become less important for all income groups and they change sign. As all economies start with the same overall economic environment as the United States, complementarities are at their highest level, overstating the reforms' impact due to this factor, but underestimating the effect of the implied small technological gap. This last effect is larger for the three higher-income groups, which explains why interactions have a positive sign. On the contrary, for low-income countries, the effect of a poor economic environment dominates the effect of a large gap, explaining the negative sign of the interactions. Here, this result implies that the possibility of growth for this type of country arises from improvement of the overall economic environment.

Table 3. Contribution to closure of the gap, by development factor and by country group: top-down measure

	a. Relative contribution					
	Years (1)	Quality (2)	Flexibility (3)	Institutions (4)	Interactions (5)	Gap (6)
HIC	0.029	0.038	0.048	0.007	0.017	0.139
UMIC	0.071	0.141	0.085	0.073	0.084	0.454
LMIC	0.091	0.141	0.082	0.195	0.108	0.617
LIC	0.179	0.233	0.121	0.329	-0.031	0.830

	b. Relative contribution					
	Years (1)	Quality (2)	Flexibility (3)	Institutions (4)	Interactions (5)	Gap (6)
HIC	0.212	0.269	0.347	0.053	0.119	1.000
UMIC	0.157	0.311	0.188	0.160	0.185	1.000
LMIC	0.147	0.229	0.133	0.316	0.175	1.000
LIC	0.201	0.261	0.135	0.368	0.035	1.000

Source: Authors' calculation.

5.2 Complementarities and the level of development

The results presented in the previous section reflect the trade-off between the level of all parameters and the technology gap. This explains why similar policy reforms have different effects on steady-state productivity and income-per-worker gaps when undertaken by countries at different stages of development. Column 1 of Table 4 shows the marginal effect on steady-state productivity of changing one policy parameter, everything else constant. All effects are positive, but the final effect depends on the stage of development through two opposing effects. On the one hand, the longer the distance to the technological frontier (1-a), the larger the gains of undertaking any reform, as the larger is the technology improvement achieved by an economy. However, on the other hand, the longer the distance to the technological frontier, the poorer the overall R&D environment (low absorptive capacity), producing lower effects from any particular reform.

Table 4: Reforms and stage of development

Marginal effects	Marginal effects and stage of development
$\partial\bar{a}/\partial\lambda = \frac{\bar{a}}{\lambda}(1-\bar{a})$ [1]	$\partial^2\bar{a}/\left[\partial\lambda\ \partial\bar{a}\right] = \frac{1}{\lambda}(1-2\bar{a})$
$\partial\bar{a}/\partial(n\beta) = \frac{\bar{a}}{n\beta}(1-\bar{a})$	$\partial^2\bar{a}/\left[\partial n\beta\ \partial\bar{a}\right] = \frac{1}{n\beta}(1-2\bar{a})$
$\partial\bar{a}/\partial q = \bar{a}(1-\bar{a})\frac{\gamma}{H}\kappa(1+q)^{\kappa-1}$	$\partial^2\bar{a}/\left[\partial q\ \partial\bar{a}\right] = (1-2\bar{a})\frac{\gamma}{H}\kappa(1+q)^{\kappa-1}$
$\partial\bar{a}/\partial\kappa = \bar{a}(1-\bar{a})\gamma\log(1+q)$	$\partial^2\bar{a}/\left[\partial\kappa\ \partial\bar{a}\right] = (1-2\bar{a})\gamma\log(1+q)$

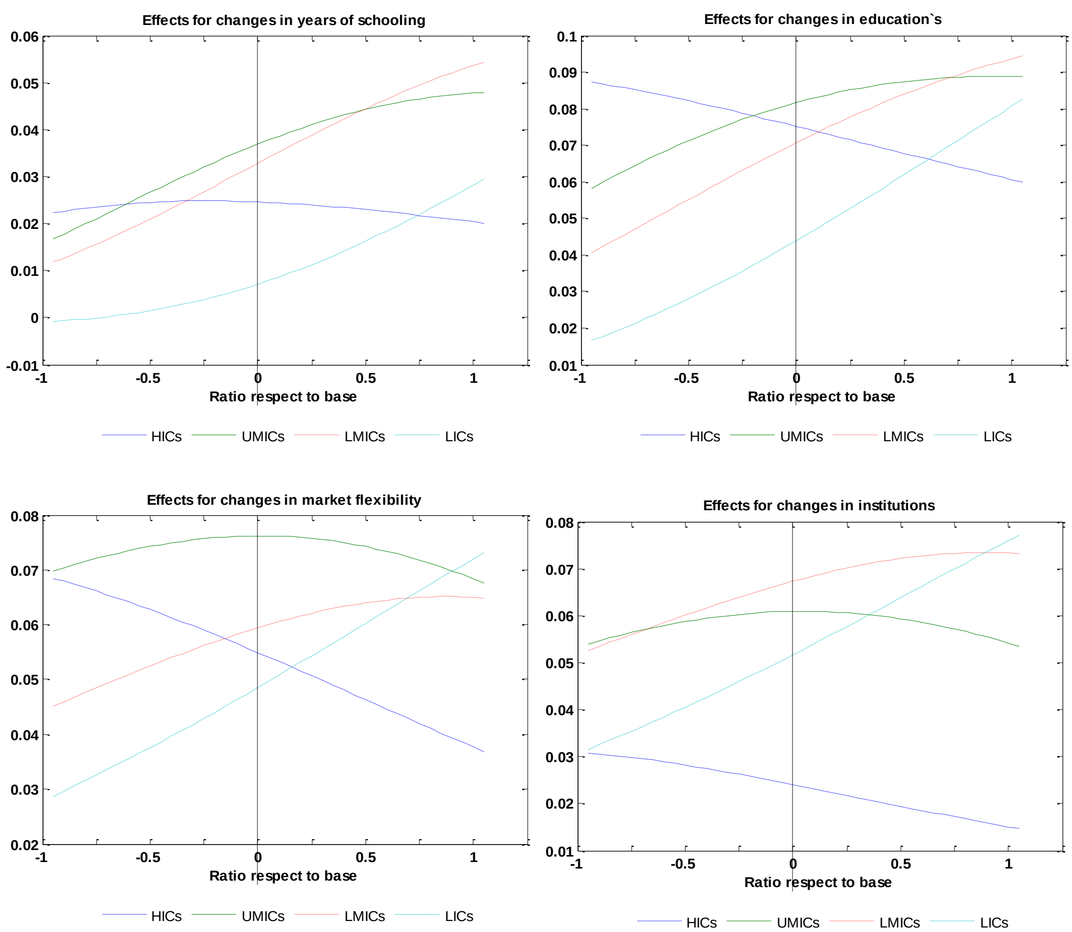
(1) $\bar{a}$ =relative technology level in steady state.

Table 1, column 1 shows that, as expected, for any initial level of technology, improving any development factor reduces the technology gap in steady state. However, the marginal effect of a particular reform depends on the stage of development.

The second column of Table 4 shows that the effects increase with the level of development, reaching a maximum at the middle stage of development ($\bar{a}$ =1/2) and then decreasing. Starting at very low development stages, all effects increase with the level of development, implying that the overall economic environment dominates the gap effect. However at a certain threshold the contrary becomes true and the impact decreases with the level of development. This result explains why almost all effects of policy reforms are lowest for low-income countries. The effects reach their maximum at the middle stage of development ($\bar{a}$ =1/2).

To further explore the non-linearities that exist in practice in the different groups of countries, we perform the following exercise: We evaluate the effect on the productivity gap of increasing each parameter by one standard deviation of its income group while keeping the value of the remaining parameters constant. Then, to capture complementarities with the other policies, we modify the values of the other parameters within a range comprising $\pm$ one standard deviation of the corresponding income group. The results are shown in the next figure. The value at x=0 corresponds to the effect of increasing the referred parameter by one standard deviation, keeping the current value of the other parameters, while values of x between -1 and 1 correspond to the effect of changing all parameters, except for the one analyzed, by one standard deviation.

Figure 1: Non-linearities in the stage of development, bottom-up effects due to changes in development factors for different set of parameters



Source: Authors' calculations. Standard deviations as reported in Table 1b.

We observe strong nonlinearities in the different policies over the productivity gap, highlighting the effect of the development stage on the outcome. Second, the effects for high-income countries are strongly decreasing in the level of the determinants of the absorptive capacity, indicating that as these countries undertake new reforms that increase their level of income, this results in smaller effects on the productivity gap. In other words, the effect of a smaller gap more than offsets the effect of having a better overall economic environment. Low-income countries, in contrast, strongly benefit from implementing several reforms simultaneously, as the poor overall environment prevents them from fully benefitting from dismantling each bottleneck separately. This effect is easily seen in the steep upward-sloping curve for low-income and lower-middle-income countries.

6. Concluding remarks

Technology adoption is a key vehicle for improving productivity in both developed and developing economies. However, this process is not automatic. It requires that economies be capable of absorbing and implementing technologies developed elsewhere. We identify four factors that are essential for shaping this absorptive capacity: the stock of human capital, which is determined by i) the quantity of education and ii) the quality of the educational system, iii) the institutional environment (barriers, rule of law, property rights) that favors or hinders the adoption activity, and iv) the microeconomic flexibility that allows the entry of firms with high productivity and the exit of firms with low productivity.

Including these factors in an analytical model of technology adoption generates a distribution of TFP gaps (with respect to the United States) that matches the empirical distribution of these gaps. It also allows us to disentangle and quantify the relative weight of these factors in explaining the TFP gaps of individual countries, country groups or regions in relation to a benchmark economy.

We perform two different exercises to assess the impact of each factor on the productivity gap. Our findings show that low-income economies require "big-bang"-type reforms as the interactions of multiple reforms enhance the overall effect. However, if an economy has to choose one reform, improving the quality of institutions provides the most significant effect on productivity. As economies progress to more advance stages of development, the quality of education becomes increasingly important in closing the gap with the leading economies. At later stages of development, the flexibility of markets becomes increasingly important to closing the gap.

The assessment of all these reforms has certain nuances, as there are important non-linearities in the relationships between productivity and the corresponding parameters. For instance, the poorer the country, the more important the levels of other factors when analyzing the impact of any reform. The opposite is true for developed economies. This implies that there is an important need for complementary reforms in less-developed economies.

REFERENCES

Acemoglu, Daron (2009). *Introduction to Modern Economic Growth.* Princeton University Press.

Acemoglu, Daron and Fabrizio Zilibotti (2001). “Productivity Differences”. *Quarterly Journal of Economics,* 116, pp. 563-606.

Banerjee, A. and E. Duflo (2005). *Growth Theory through the Lens of Development Economics.* In P. Aghion and S. N. Durlauf (Eds.), Handbook of Development Economics, pp. 473--552.Elsevier B.V.

Bartelsman, Eric, Haltiwanger, John and Stefano Scarpetta (2012). “Cross-country Differences in Productivity: The Role of Selection and Selection”. *NBER Working Paper* 15490.

Barro, Robert and Jong-Wha Lee (2010). "A New Data Set of Educational Attainment in the World, 1950-2010." NBER Working Paper No. 15902.

Benhabib, Jess and Mark Spiegel (2002). Human Capital and Technology Diffusion. Proceedings, Federal Reserve Bank of San Francisco, issue Nov.

Caselli, Francesco (2005). “Accounting for Cross-Country Income Differences”.. In P. Aghion and S. N. Durlauf (Eds.), Handbook of Development Economics, pages 473-552. Elsevier B.V.

Comin, Diego and Bart Hobijn (2004). “Cross-country technology adoption: making the theories face the facts”. *Journal of Monetary Economics* 51, pages: 39–83

Córdoba , Juan Carlos and Marla Ripoll (2008). “Endogenous TFP and Cross-Country Income Differences.” *Journal of Monetary Economics* 55, pages: 1158–1170

Gollin, Douglas (2002). "Getting Income Shares Right," Journal of Political Economy, vol. 110(2), pages 458-474.

Hall, Robert E. and Charles I. Jones (1999). Why Do Some Countries Produce so Much More Output per Worker than Others? Quarterly Journal of Economics, vol. 114, pages 83-116.

Howitt, Peter (2000). Endogenous Growth and Cross-Country Income Differences. American Economic Review, vol. 90, pages 829-46.

Hsieh, Chang-Tai and Peter J. Klenow (2009). "Misallocation and Manufacturing TFP in China and India", Quarterly Journal of Economics 124, November, 1403-1448

Klenow, Peter J. and Andrés Rodríguez-Clare (1997). The Neoclassical Revival in Growth Economics: Has it Gone too Far? In NBER Macroeconomics Annual1997, edited by Ben Bernanke and Julio Rotemberg, pages 73-103. Cambridge, MA: MIT Press.

Nelson, Richard and Edmund S. Phelps (1966). Investment in Humans, Technological Diffusion, and Economic Growth. American Economic Review, 56, pages 69-75.

Parente, Stephen and Edward C. Prescott (1994). Technology Adoption and Growth. Journal of Political Economy, vol. 102, pages 298-321.

Parente, Stephen and Edward C. Prescott (1999). Monopoly Rights: A Barrier to Riches. American Economic Review, vol. 89, pages 1216-33.

Parente, Stephen and Edward C. Prescott (2002). Barriers to Riches. MIT Press.

Restuccia, D. and R. Rogerson (2008). "Policy Distortions and Aggregate Productivity with Heterogeneous Plants. " Review of Economic Dynamics, vol. 11(4), pages 707-720, October.

Schoellman, T. (2012). "Education Quality and Development Accounting”. Review of Economic Studies, vol. 79 (1), pages 388-417.

Appendices

Table A1. Country sample by income group

HIC	UMIC	LMIC	LIC
Australia	Greece	Bolivia	Haiti
Belgium	Algeria	Albania	Bangladesh
Canada	Argentina	Cameroon	Cambodia
Denmark	Brazil	China	Ghana
Finland	Bulgaria	El Salvador	Kenya
France	Chile	Fiji	Laos
Germany	Colombia	Guyana	Nepal
Hong Kong	Costa Rica	Honduras	Senegal
Ireland	Croatia	India	Sudan
Israel	Czech Republic	Indonesia	Tanzania

HIC	UMIC	LMIC	LIC
Italy	Egypt	Jamaica	Uganda
Japan	Guatemala	Moldova	
Korea, Rep.	Hungary	Nicaragua	
Norway	Iran	Pakistan	
Singapore	Jordan	Paraguay	
Spain	Latvia	Peru	
Sweden	Malaysia	Philippines	
United Kingdom	Mexico	Sri Lanka	
	Trinidad and Tobago	Syria	
	Panama	Morocco	
	Poland	Vietnam	
	Portugal		
	Romania		
	South Africa		
	Thailand		
	Turkey		
	Ukraine		
	Venezuela		

Table A2. Country parameters by income group

HIC	Years of Schooling	Quality	Flexibility	Institutions
Australia	12.12	0.081	0.090	0.92
Belgium	10.55	0.098	0.073	0.95
Canada	11.37	0.088	0.066	0.98
Denmark	10.06	0.070	0.125	1.00
Spain	10.38	0.048	0.067	0.87
Finland	9.97	0.056	0.076	1.01
France	10.53	0.077	0.096	0.92
Great Britain	9.59	0.099	0.090	0.98
Germany	11.82	0.083	0.080	0.95
Ireland	11.64	0.074	0.105	0.94
Italy	9.51	0.041	0.134	0.86
Japan	11.58	0.106	0.041	0.97
The Netherlands	11.02	0.096	0.031	1.00
Norway	12.30	0.104	0.095	0.94
Sweden	11.57	0.115	0.068	1.02
Trinidad and Tobago	9.62	0.050	0.101	0.53
Hong Kong	10.37	0.080	0.128	0.83
Korea	11.85	0.019	0.099	0.90
Singapore	9.14	0.078	0.112	1.00
Israel	11.33	0.076	0.126	1.00
Median	10.78	0.079	0.093	0.95
St. Dev.	0.97	0.024	0.028	0.11

UMIC	Years of schooling	Quality	Flexibility	Institutions
Greece	10.68	0.041	0.055	0.80
Portugal	7.99	0.020	0.075	0.79
Argentina	9.35	0.065	0.077	0.76
Brazil	7.54	0.048	0.095	0.65
Chile	10.18	0.056	0.119	0.75
Colombia	7.69	0.026	0.059	0.46
Costa Rica	8.68	0.025	0.083	0.67
Guatemala	4.80	0.007	0.064	0.31
Mexico	9.11	0.008	0.071	0.63
Panama	9.58	0.061	0.085	0.60
Venezuela	7.02	0.051	0.078	0.65
Malaysia	10.14	0.081	0.094	0.69
Thailand	7.50	0.027	0.101	0.60
Bulgaria	9.85	0.049	0.132	0.60
Czech Rep.	12.13	0.046	0.062	0.79
Croatia	8.99	0.040	0.039	0.80
Hungary	11.65	0.091	0.098	0.84
Latvia	10.60	0.054	0.084	0.66
Poland	9.87	0.031	0.048	0.72
Romania	10.37	0.049	0.096	0.55
Turkey	7.02	0.049	0.104	0.55
Ukraine	11.12	0.056	0.069	0.66
Algeria	7.70	0.051	0.105	0.34
Egypt	7.08	0.058	0.026	0.53
Iran	8.14	0.066	0.089	0.27
Jordan	9.23	0.030	0.075	0.65
Morocco	5.00	0.054	0.080	0.42
South Africa	8.56	0.099	0.064	0.71
Median	9.05	0.049	0.079	0.652
St. Dev.	1.80	0.022	0.023	0.151

LMIC	Years of schooling	Quality	Flexibility	Institutions
Bolivia	9.91	0.018	0.074	0.37
Guyana	8.56	0.056	0.088	0.48
Honduras	7.49	0.008	0.064	0.38
Jamaica	9.87	0.056	0.052	0.63
Nicaragua	6.74	0.024	0.054	0.21
Peru	9.02	0.027	0.089	0.42
Paraguay	8.53	0.043	0.079	0.45
Salvador	7.97	0.008	0.081	0.36
China	8.17	0.060	0.045	0.46
Fiji	11.34	0.055	0.086	0.54
Indonesia	6.24	0.057	0.045	0.23
The Philippines	8.97	0.055	0.076	0.42
Vietnam	6.43	0.020	0.096	0.25
Albania	10.26	-0.010	0.092	0.31
Moldova	9.67	0.050	0.084	0.46
Syria	5.28	0.032	0.086	0.37
India	5.12	0.068	0.042	0.40
Sri Lanka	8.45	0.065	0.086	0.34
Pakistan	5.59	0.048	0.099	0.24
Cameroon	6.07	0.059	0.036	0.30
Median	8.31	0.049	0.080	0.38
St. Dev.	1.80	0.022	0.020	0.11

LIC	Years of schooling	Quality	Flexibility	Institutions
Haiti	5.17	0.028	0.022	0.25
Cambodia	6.04	0.008	0.053	0.17
Lao	5.09	0.004	0.096	0.16
Bangladesh	5.79	0.033	0.068	0.16
Nepal	3.97	0.002	0.079	0.21
Ghana	7.75	0.043	0.061	0.23
Kenya	7.31	0.059	0.053	0.44
Sudan	3.28	0.010	0.085	0.14
Senegal	5.20	0.036	0.042	0.32
Tanzania	5.54	0.127	0.066	0.23
Uganda	5.37	0.024	0.100	0.28
Median	5.37	0.028	0.066	0.23
St. Dev.	1.28	0.036	0.023	0.09

Table A3. Bottom-up measure, by country

HIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Australia	0.002	0.042	0.071	0.017	-0.013	0.118
Belgium	0.051	-0.017	0.112	0.011	-0.014	0.143
Canada	0.025	0.019	0.136	0.004	-0.015	0.168
Denmark	0.045	0.064	0.007	0.001	0.000	0.117
Finland	0.050	0.134	0.136	-0.004	-0.028	0.288
France	0.042	0.053	0.066	0.020	-0.020	0.161
Germany	0.010	0.036	0.096	0.011	-0.015	0.138
Great Britain	0.073	-0.017	0.071	0.004	-0.013	0.117
Hong Kong	0.043	0.038	0.002	0.038	-0.008	0.113
Ireland	0.013	0.061	0.042	0.013	-0.012	0.118
Israel	0.018	0.047	0.004	0.000	-0.001	0.068
Italy	0.042	0.163	-0.011	0.039	0.010	0.244
Japan	0.024	-0.055	0.225	0.007	0.011	0.211
Korea	0.003	0.314	0.075	0.031	-0.039	0.384
Norway	-0.002	-0.032	0.044	0.010	0.006	0.025
Singapore	0.072	0.041	0.031	-0.001	-0.006	0.138
Spain	0.037	0.183	0.181	0.041	-0.050	0.392
Sweden	0.019	-0.071	0.098	-0.003	0.019	0.061
The Netherlands	0.046	-0.013	0.330	0.001	-0.016	0.347
Trinidad and Tobago	0.055	0.166	0.071	0.182	-0.048	0.427

UMIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Algeria	0.094	0.128	0.057	0.309	-0.009	0.578
Argentina	0.076	0.102	0.143	0.078	-0.050	0.350
Brazil	0.096	0.138	0.089	0.124	-0.012	0.433
Bulgaria	0.047	0.159	-0.007	0.134	-0.023	0.309
Chile	0.043	0.128	0.020	0.074	-0.022	0.243
Colombia	0.039	0.185	0.200	0.196	0.092	0.712
Costa Rica	0.037	0.241	0.125	0.116	0.003	0.523
Croatia	0.050	0.187	0.335	0.059	-0.009	0.622
Czech Rep.	0.001	0.223	0.207	0.070	-0.081	0.421
Egypt	0.086	0.067	0.400	0.135	0.100	0.787
Greece	0.027	0.225	0.242	0.064	-0.061	0.498
Guatemala	0.012	0.111	0.137	0.252	0.303	0.816
Hungary	0.015	0.007	0.053	0.034	-0.010	0.098
Iran	0.106	0.082	0.099	0.366	-0.029	0.624
Jordan	0.037	0.237	0.156	0.124	-0.018	0.537
Latvia	0.037	0.161	0.121	0.117	-0.060	0.376
Malaysia	0.061	0.043	0.080	0.091	-0.041	0.234
Mexico	0.009	0.312	0.161	0.122	0.032	0.637
Morocco	0.155	0.071	0.129	0.240	0.044	0.639
Panama	0.068	0.122	0.120	0.146	-0.058	0.398
Poland	0.028	0.245	0.277	0.089	-0.023	0.617
Portugal	0.036	0.239	0.155	0.067	0.032	0.529
Romania	0.038	0.182	0.086	0.171	-0.058	0.419
South Africa	0.139	-0.020	0.185	0.094	-0.071	0.327
Thailand	0.054	0.203	0.071	0.148	0.031	0.507
Turkey	0.109	0.126	0.062	0.174	-0.005	0.465
Ukraine	0.026	0.164	0.178	0.118	-0.073	0.412
Venezuela	0.113	0.120	0.148	0.126	-0.011	0.496

LMIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Albania	-0.005	0.376	0.065	0.273	0.083	0.791
Bolivia	0.013	0.277	0.136	0.257	0.035	0.718
Cameroon	0.088	0.044	0.265	0.248	0.194	0.839
China	0.088	0.094	0.287	0.209	0.006	0.683
Salvador	0.010	0.242	0.107	0.257	0.125	0.741
Fiji	0.020	0.171	0.116	0.176	-0.075	0.407
Guyana	0.087	0.129	0.110	0.211	-0.043	0.493
Honduras	0.010	0.210	0.154	0.224	0.176	0.774
India	0.158	0.035	0.271	0.216	0.085	0.765
Indonesia	0.081	0.048	0.204	0.312	0.194	0.840
Jamaica	0.054	0.148	0.260	0.133	-0.059	0.536
Moldova	0.053	0.169	0.122	0.225	-0.052	0.517
Nicaragua	0.024	0.098	0.141	0.310	0.294	0.869
Pakistan	0.110	0.082	0.060	0.384	0.086	0.722
Paraguay	0.064	0.170	0.137	0.229	-0.011	0.589
Peru	0.033	0.238	0.100	0.244	0.006	0.621
Sri Lanka	0.100	0.093	0.116	0.309	-0.044	0.573
Syria	0.080	0.114	0.100	0.269	0.125	0.689
The Philippines	0.073	0.136	0.150	0.247	-0.041	0.565
Vietnam	0.034	0.151	0.060	0.356	0.158	0.760

LIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Bangladesh	0.042	0.070	0.095	0.389	0.270	0.866
Cambodia	0.007	0.087	0.112	0.299	0.402	0.905
Ghana	0.050	0.106	0.155	0.351	0.141	0.803
Haiti	0.021	0.037	0.236	0.164	0.477	0.934
Kenya	0.108	0.088	0.239	0.223	0.014	0.671
Lao	0.005	0.103	0.041	0.404	0.301	0.856
Nepal	0.003	0.083	0.076	0.336	0.350	0.848
Senegal	0.058	0.067	0.219	0.229	0.266	0.840
Sudan	0.015	0.049	0.052	0.399	0.364	0.880
Tanzania	0.328	-0.055	0.173	0.403	-0.166	0.683
Uganda	0.054	0.124	0.057	0.336	0.160	0.730

Table A3. Bottom-up measure, by country

HIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Australia	0.002	0.032	0.059	0.012	0.014	0.118
Belgium	0.035	-0.012	0.100	0.007	0.013	0.143
Canada	0.017	0.013	0.121	0.002	0.015	0.168
Denmark	0.046	0.065	0.005	0.000	-0.000	0.117
Finland	0.048	0.114	0.092	-0.002	0.036	0.288
France	0.035	0.043	0.048	0.013	0.021	0.161
Germany	0.008	0.026	0.082	0.008	0.015	0.138
Great Britain	0.057	-0.014	0.059	0.003	0.012	0.117
Hong Kong	0.039	0.035	0.001	0.029	0.009	0.113
Ireland	0.011	0.053	0.032	0.009	0.012	0.118
Israel	0.018	0.046	0.003	0.000	0.001	0.068
Italy	0.060	0.174	-0.006	0.023	-0.007	0.244
Japan	0.012	-0.029	0.237	0.004	-0.012	0.211
Korea	0.007	0.277	0.042	0.016	0.043	0.384
Norway	-0.002	-0.025	0.049	0.009	-0.006	0.025
Singapore	0.069	0.040	0.022	-0.000	0.007	0.138
Spain	0.039	0.145	0.118	0.022	0.069	0.392
Sweden	0.013	-0.047	0.117	-0.003	-0.020	0.061
The Netherlands	0.024	-0.007	0.314	0.000	0.015	0.347
Trinidad and Tobago	0.057	0.137	0.039	0.116	0.078	0.427

UMIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Algeria	0.108	0.133	0.032	0.222	0.083	0.578
Argentina	0.064	0.082	0.091	0.045	0.069	0.350
Brazil	0.112	0.145	0.050	0.072	0.054	0.433
Bulgaria	0.051	0.141	-0.004	0.088	0.033	0.309
Chile	0.043	0.114	0.011	0.047	0.028	0.243
Colombia	0.108	0.242	0.148	0.145	0.069	0.712
Costa Rica	0.081	0.247	0.074	0.067	0.054	0.523
Croatia	0.073	0.179	0.249	0.035	0.087	0.622
Czech Rep.	0.001	0.153	0.137	0.038	0.091	0.421
Egypt	0.126	0.107	0.365	0.116	0.073	0.787
Greece	0.032	0.174	0.163	0.035	0.094	0.498
Guatemala	0.198	0.338	0.131	0.242	-0.093	0.816
Hungary	0.011	0.005	0.044	0.027	0.010	0.098
Iran	0.095	0.078	0.061	0.280	0.109	0.624
Jordan	0.067	0.224	0.094	0.073	0.079	0.537
Latvia	0.034	0.122	0.073	0.070	0.079	0.376
Malaysia	0.044	0.032	0.052	0.061	0.045	0.234
Mexico	0.070	0.333	0.105	0.078	0.052	0.637
Morocco	0.191	0.122	0.082	0.167	0.077	0.639
Panama	0.058	0.096	0.071	0.089	0.084	0.398
Poland	0.051	0.219	0.195	0.054	0.097	0.617
Portugal	0.099	0.272	0.094	0.037	0.027	0.529
Romania	0.039	0.141	0.048	0.108	0.083	0.419
South Africa	0.084	-0.014	0.131	0.056	0.070	0.327
Thailand	0.113	0.238	0.039	0.089	0.028	0.507
Turkey	0.127	0.141	0.033	0.108	0.055	0.465
Ukraine	0.022	0.114	0.114	0.069	0.093	0.412
Venezuela	0.127	0.133	0.088	0.074	0.074	0.496

LMIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Albania	0.041	0.429	0.056	0.245	0.020	0.791
Bolivia	0.050	0.281	0.099	0.199	0.089	0.718
Cameroon	0.157	0.103	0.276	0.258	0.046	0.839
China	0.095	0.099	0.215	0.149	0.125	0.683
Salvador	0.100	0.333	0.081	0.207	0.021	0.741
Fiji	0.018	0.118	0.067	0.112	0.093	0.407
Guyana	0.084	0.114	0.063	0.136	0.096	0.493
Honduras	0.114	0.333	0.129	0.191	0.008	0.774
India	0.187	0.072	0.229	0.180	0.097	0.765
Indonesia	0.151	0.110	0.213	0.323	0.042	0.840
Jamaica	0.051	0.114	0.177	0.079	0.115	0.536
Moldova	0.056	0.137	0.071	0.147	0.106	0.517
Nicaragua	0.136	0.252	0.171	0.358	-0.047	0.869
Pakistan	0.172	0.145	0.043	0.317	0.045	0.722
Paraguay	0.085	0.166	0.084	0.153	0.101	0.589
Peru	0.072	0.238	0.061	0.168	0.083	0.621
Sri Lanka	0.087	0.082	0.069	0.222	0.114	0.573
Syria	0.182	0.214	0.068	0.201	0.024	0.689
The Philippines	0.073	0.118	0.092	0.166	0.116	0.565
Vietnam	0.145	0.272	0.047	0.306	-0.011	0.760

LIC	Years of schooling	Quality	Flexibility	Institutions	Interactions	Gap
Bangladesh	0.165	0.210	0.114	0.434	-0.058	0.866
Cambodia	0.157	0.333	0.174	0.411	-0.169	0.905
Ghana	0.106	0.166	0.142	0.329	0.061	0.803
Haiti	0.186	0.233	0.413	0.311	-0.209	0.934
Kenya	0.119	0.103	0.171	0.158	0.120	0.671
Lao	0.188	0.354	0.048	0.436	-0.170	0.856
Nepal	0.226	0.364	0.084	0.356	-0.183	0.848
Senegal	0.185	0.196	0.230	0.240	-0.010	0.840
Sudan	0.251	0.322	0.069	0.467	-0.229	0.880
Tanzania	0.174	-0.067	0.121	0.326	0.130	0.683
Uganda	0.179	0.252	0.041	0.274	-0.016	0.730