Productivity Differences in Developing and Developed Countries: Where are the Bottlenecks?

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Abstract

Differences in productivity explain differences in per capita income. Productivity dynamics depends on the economy´s absorptive capacity and the productivity gap respect to leading economies. We build a theoretical model of technology adoption that successfully replicates the distribution of TFP gaps across developed and developing economies. The model focuses on four factors that shape the absorptive capacity of a country and thus, its possibility to catch-up with the leader, namely: quantity and quality of its stock of human capital; microeconomic flexibility that favors the entry and exit of firms; and the overall institutional environment that enhances/impedes R&D activities. For the calibration, the US is considered the leading economy. Simulations of the model allow us to identify the main bottlenecks faced by each country in its effort for catching-up. The major contribution of this work is to provide for each country an estimation of the productivity gain when improving each of the factors explaining the absorptive capacity. Simulations conclude that improving the quality of the education system and increasing the microeconomic flexibility of the markets are top priorities for developing economies. These economies face further problems to increase their level of productivity as they often have, simultaneously, other factors determining productivity at a low level. On the other hand, developed countries mainly have problems associated to microeconomic rigidities; though, these are not as severe as in developing countries. Moreover, developed economies are favored by having the other development factors at higher levels; for instance, quality and quantity of education.

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

1 Motivation

Differences in per capita income across the world have shaped the research agenda of economic development area. The consensus today is that differences in total factor productivity (TFP) seem to explain the largest fraction of per capita income gaps. The profession has been searching for theories that explain these differences. When studying the process of productivity dynamics, the adoption of advanced technologies appears as a natural vehicle to close these gaps. In this type of model adoption is the engine of growth. The driving force of growth and income gaps is the absorptive capacity of the economy, which is determined by the stock of human capital, economic policies and quality of institutions.

While most of the literature focuses on explaining analytically the factors inducing more/less adoption, there are fewer attempts to size the effects of these factors on TFP dynamics. This paper attempts to fill this gap in the literature accomplishing two goals: First, building a simple model that accounts for the underlying factors behind the TFP distribution across countries. Second, measuring the contribution of each identified variable to explain the productivity gap in a broad sample of developing and developed countries. The main goal here is to quantify for every country the fraction of the gap that is explained by each of the factors mentioned above.

The analytical model of adoption builds upon four factors that explain the adoption absorptive capacity of a country, namely: the stock of human capital, which depends on quantity and quality of the education system, the institutional environment associated to technological adoption; and the microeconomic flexibility of the economy. This last factor is related to all policies that enhance the process of entry and exit of firms, thus facilitating the process of technology renewal. We calibrate this model using the corresponding parameters of 33 countries; 11 developing and 22 developed economies, and we show that the proposed theoretical framework successfully replicates the distribution of productivity gaps respect to the US. Then, we conduct two exercises to assess the contribution of each factor in explaining the productivity gap with the US. The first exercise assumes that all the economies are US like, that is to say, they have the same parameter of a leading economy and, hence, the gap is equal to zero. Then we change one parameter to the corresponding value for each economy and we count the effect of that change in the productivity gap. We conduct this exercise for each parameter at the time. We also find that the sum of all these effects is smaller than the gap to be closed as there is a complementarity effect that arises when performing all policy reforms simultaneously. The second exercise starts with the current situation of the country; that is, all parameters and variables are at their current level. Consequently, the corresponding gap is the one observed in the data. Then, we change one parameter at the time to the value of the leader's and we quantify the change in the gap.

Both exercises show that challenges for developing and developed countries are different. Developing countries have major differences in all development factors respect to the US, but they need to put efforts mainly in improving their stock (quantity and quality) of human capital. They do not only have considerably fewer years of schooling compared to the US, but they also exhibit a poorer education system. These countries also show on average large microeconomic rigidities that obstruct the process of entry and exit of firms and hence, the process of creative destruction. The model also generates complementarities between different policy actions. These complementarities are especially relevant for developing countries, since they are lagged in all areas of development. The policy implication of this fact is that policy improvements will have larger effects when they are implemented together.

Developed countries, in contrast, show a different picture. Bottlenecks are less restrictive than in the developing world. Nevertheless, microeconomic rigidities arise also in this group as a main factor explaining TFP gaps; though this group performs better in this category than the developing world. Moreover, this group tends to have better parameters in all other areas, which reduce the negative effect of microeconomic rigidities on the TFP gap. In fact, many developed countries perform better in some areas than the US. This is especially true for the quality of the education system.

This paper continues the strand in the literature that focuses on TFP differences as the main factor explaining per capita income differences (Knight et al, 1993; Islam, 1995; Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999; Casselli, 2004 among others). Within the model for TFP, there are several papers that stress the importance of the mentioned factors as promoters or inhibitors of TFP improvement. For instance, Acemoglu (2009), and the references therein, largely discusses the role of institutions in promoting the adoption activity. There is also a large bulk of empirical and theoretical literature that emphasizes the effects of misallocation of resources on the average productivity of the economy (see, for instance, Hopenhayn, 1992, Parente and Prescott 2000, Lagos 2006, Banerjee and Duflo 2005, Jeong and Townsend 2007, Restuccia and Rogerson 2008, Hsieh and Klenow, 2009, Bartelsman et al., 2008).

This paper is organized as follows: After this introduction, the next section outlines the analytical model and discusses the main mechanisms under analysis. The third section presents the simulations and the contrast with the data. Here, we discuss the main estimations and the general performance of the proposed model. The fourth section uses the model to disentangle the relative weight of each channel in explaining the TFP gap in every economy. We also derive general lessons for the broader group of developing and developed countries. Section 5 presents some concluding remarks.

2 The analytical model

The model follows closely Howitt (2000). Consider one small and open economy out of J countries. This economy trades only the final consumption good and is open to capital flows. The economy is composed of two types of sectors: An homogenous and competitive final goods sector and an intermediate sector producing different qualities of inputs. The intermediate sector comprises a continuum of monopolies producing the productive inputs and R&D firms trying to improve the technologies embedded in these inputs.

Every firm is aware of the technologies available elsewhere. This awareness, however, does not imply that technologies can be implemented or mastered for free. Everyone using a technology has to have attained it through costly R&D. Technologies are general, and not rival. Technological progress results from the efforts made to adopt the technological frontier. This frontier grows exogenously at the constant rate g. Technology adoption requires human capital to be performed. We assume that human capital is heterogenous at the world level.

There is also a continuum of households that live infinitely. Households derive utility from the consumption of the final good only and supply inelastically their endowment of labor. There is no population growth. The framework used ensures that there is no aggregate risk. We further assume that markets are complete and that there is perfect access to foreign capitals. Under this setting, consumption and production decisions are independent. Optimal financial wealth allocation, in contrast, implies some arbitrage conditions that are used to derive some equilibrium relations.[1] Moreover, the complete development path of an economy can be characterized by studying the productive and R&D decisions and by exploiting the mentioned arbitrage conditions. All decisions are made at the disaggregate level and follow the Schumpeterian growth literature. We start presenting the firms' problem in the final and in the intermediate production sectors.

[1] In particular, net return on physical capital, return on foreign bonds, and expected return on stocks are all equal in equilibrium.

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 equation (1). Input i embeds a productivity level of A_{it}. The higher the productivity embedded in inputs x_{it}, the higher the quantity of Y_t that one unit of x_{it} generates.

$$Y_t = L^{1-\alpha} \int_0^1 A_{it} x_{it}^{\alpha} di \tag{1}$$

The intermediate sector comprises two types of firms: a monopoly and an R&D firm. Monopoly i produces intermediate input i. Inputs differ in the productivity that they provide. The monopoly in sector i produces input i with the following technology: $x_i(t) = K_i(t)/A_i(t)$. Physical capital requirements to produce one unit of $x_i(t)$ depend on the technology level embedded in $x_i(t)$. The higher $A_i(t)$, the more physical capital is needed to embed this technology in $x_i(t)$. Firm i sells inputs i to the final goods firm at the monopoly price $p_i(t)$ and pays for the use of capital its competitive rental price $r(t)$. The firm chooses optimally the amount $x_i(t) = L\left(\alpha^2/r(t)\right)^{1/(1-\alpha)}$ which only depends on two aggregate variables: the rental price of capital and the total flow of labor.[2] Perfect access to foreign capital ensures that $r(t) = r_B + \delta$ in equilibrium. The world is in steady state so that r_B is constant. Optimal $x_i(t)$ is independent of the level of technology embedded in the input. Therefore, every sector supplies an equal amount of inputs. Monopolists' profits, in contrast, depend on the technology embedded in input $x_i(t)$ and correspond to $A_i(t)\pi(t)$ as defined in equation (2).

$$A_{it}\pi_t, \text{ where } \pi_t \equiv \alpha(1-\alpha)\left(\alpha^2/(r_B+\delta)\right)^{\alpha/(1-\alpha)} L \tag{2}$$

The flow π_t is equal across sectors as it depends only on aggregate variables. Moreover, it is constant. Differences in monopolists' profits are solely explained by differences in the productivity provided by the input. R&D firm i is outside the market and it is investing in R&D to improve the technology in sector i.

[2] Optimal amount of $x_{it} = \arg\max_{x_{it}}[p_{it}x_{it} - rK_{it}]$.

2.2 The R&D Market

Every sector comprises an R&D firm that is investing to improve the current technology in use in sector i. Success is stochastic. Thus, the monopoly duration is also stochastic. When the R&D firm produces this improvement, the previous monopoly stops producing and starts engaging in R&D activities.

2.2.1 R&D's decision problem

R&D firms engage in R&D activities to improve the current technology embedded in input i to get monopoly profits (equation 2). The R&D firm chooses the amount to invest by considering profits and expenses in R&D. The technology improvement depends on the resources invested by the R&D firm and on the adoption capacity that exists in the economy.

We assume that investment in R&D only affects the probability of success[3] defined as $n_{it}\beta$, where $n_{it} \equiv I_{it}/\overline{A}_{it}$, that is R&D resources I_{it} scaled by the complexity of the aimed technology $\overline{A}_{it}$ and β, the productivity of R&D (equation, 4). The R&D firm chooses the amount I_{it} to invest by considering the expected profits W_{it} equation (3) that it will get if (it is successful) and the expenses in R&D.

The present value of a successful R&D firm W_{it} is given by equation (3) which corresponds to the profits of the monopoly for as long as it remains producing. According to equation (2), time t's profits are given by the term $\overline{A}_{it}\pi_t$, where $\overline{A}_{it}$ is the level of technology that a successful R&D firm achieves. This technology level is constant for the whole period in which the firm remains as the monopoly. The firm discounts its flows at the cost of capital r_t if it remains in the market (with probability $1-\phi_t$) The displacement rate ϕ_t corresponds to the probability that the rival firm obtains an improved technology in the future.

$$W_{it} = \overline{A}_{it} w_{it} = \sum_{t}^{\infty} \frac{\overline{A}_{it}\pi_t (1-\phi_t)}{(1+r_t)^{t-1}} \tag{3}$$

Although risk is idiosyncratic, there is no aggregate risk and firms maximize the expected net benefit from R&D as in equation (4). Parameter τ comprises all subsidies/taxes imposed to the

[3] Assuming that R&D investment only affects the probability of success and not the technology improvement simplifies the discussion of the mechanisms and makes the model more tractable. The cost is that the framework does not allow analyzing how the technology improvement in a particular sector is affected by the resources invested. However, resources invested in every sector affect the average technology improvement of the economy (section 4 discusses implications for aggregate relations).

R&D resources involved. The maximization problem corresponds to:

$$\max_{I_{it}} \frac{\left(I_{it}/\overline{A}_{it}\beta\right)\ W_{it}}{1+r_t} - I_{it}(1+\tau) \tag{4}$$

$$FOC : \beta w_{it} = (1+\tau)\,(1+r_t) \tag{5}$$

Note, that if τ is constant, w_{it} has to be constant too. Moreover, as there is no aggregate risk, in equilibrium the cost of capital is equal to the constant risk-free rate r_B. As a consequence, from equation (3), we obtain that the displacement rate ϕ_t has to be constant as well.

$$w_t = w = \frac{\pi\,(1+r_B)}{r_B+\phi} \tag{6}$$

In a symmetric equilibrium, the displacement rate corresponds to the probability of success $n\beta$. Thus, replacing equation (6) in the FOC, we can obtain the optimal amount of R&D resources invested as in the following equation:[4]

$$n_{it} = n = \frac{\pi}{(1+\tau)} - \frac{r_B}{\beta} \tag{7}$$

$$I_{it} = \overline{A}_{it} n \tag{8}$$

$$n\beta = \frac{\beta\pi}{(1+\tau)} - r_B \tag{9}$$

Effective R&D investment depends positively on the flow of profits that the R&D firm obtains and on the country's productivity parameter β. As expected, it depends negatively on both, the interest rate r_B and the tax rate τ. Finally, the larger the expected technology improvement $\overline{A}_{it}$, the more resources I_{it} are invested in R&D.

The displacement rate (and so the probability of success) $n\beta$ is key for our empirical exercises. This rate corresponds to the rate of creative destruction and defines the entry and exit of firms. A healthy rate of entry and allows firms to remain competitive in the world market. This rate depends positively on expected profits π and R&D productivity β and negatively on taxes and on the cost of capital. In a broader setting, this rate depends on all regulations, taxes, subsidies that affect the entry and exit of firms and is associated to microeconomic conditions of the economy.

[4] Interior solutions and probability bounded in the range $[0,1]$ require $r_B(t)/\pi(t) \leq \beta \leq (1+r_B(t))/\pi(t)$.

The technology improvement $\overline{A}_{it}$ We assume that R&D comprises mainly an adoption activity. Adoption corresponds to the copy of existing technologies. If successful, the R&D firm can accomplish the technology level $\overline{A}_{it}$, which is defined as:

$$\overline{A}_{it} \equiv A_{it-1} + n_t \beta \lambda \left(H_{t-1}/H^*_{t-1} \right)^{\gamma} \left(A_{\max t-1} - A_{it-1} \right) \tag{10}$$

$$\gamma \geq 0$$

$$\lambda \in [0,1]$$

Adoption depends on the technology gap $(A_{\max t} - A_{it})$, where $A_{\max t}$ is the technology frontier. Adoption also depends on barriers, policies, institutions, or incentives to copy foreign technologies.[5] Parameter λ comprises all institutional effects reflecting the kind of barriers emphasized by Parente and Prescott (1994). It fluctuates in the range $[0,1]$. We will refer to λ as the adoption barriers' parameter. No barriers to adopt new technologies implies a value for λ equal to one and, conversely, maximum barriers imply a $\lambda = 0$. The value of this parameter can vary across countries. The term $(H_t/H^*_t)^{\gamma}$ accounts for the role of human capital needed in the adoption activity. Adopting a new technology is not an automatic process in the sense that it requires human capital to be performed. We assume further that the relevant stock of human capital does not only depend on its absolute stock, but on the complexity of the targeted technology, which we assume is the technological frontier. As a proxy of the human capital needed to fully copy this technology we use the stock of human capital of the countries that are systematically moving the technological frontier. This stock is denoted by the variable $H^*$and corresponds to the stock of human capital of the stand-in leading economy.

2.2.2 The aggregate equilibrium

Summing up the sectoral equilibrium for every economy, we get the aggregate equilibrium. As there is no aggregate risk, every period a fraction $n_j \beta_j$ of the R&D is successful. The law of motion of the average productivity A_t of every country j evolves as:

$$A_{t,j} = A_{t-1,j} + n_j \beta_j \left[\lambda_j \left(H_{t-1,j}/H^*_{t-1} \right)^{\gamma} \left(A_{\max t-1} - A_{it-1} \right) \right] \qquad j = 1, 2, 3 ... J \tag{11}$$

[5] For example, access to 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.

Regarding the stock of human capital, we assume that it is constant and heterogenous at the world level so that $H_{t,,j} = H_j$, $j = 1, 2, 3...J$. Finally, adding up all the sectors we obtained the following neoclassical representation for the aggregate production function:

$$Y_{t,j} = K^{\alpha} \left(A_{t,j} L\right)^{1-\alpha}$$

2.2.3 The steady state

The steady state is characterized by the solution of equation (11). Stating it in terms of the technology frontier, we obtain the following solution for the relative average productivity of country j.

$$a_{ss},_j \equiv \frac{A_t,_j}{A_{\max t},_j} = \frac{n_j \beta_j \lambda_j \left(H_j/H^*\right)^{\gamma}}{\left[g + n_j \beta_j \lambda_j \left(H_j/H^*\right)^{\gamma}\right]} \qquad j = 1, 2, 3...J \tag{12}$$

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

$$\frac{a_{ss},_j}{a^*_{ss}} = \frac{n_j \beta_j \lambda_j \left(H_j/H^*\right)^{\gamma}}{n^* \beta^* \lambda^*} \frac{\left[g + n^* \beta^* \lambda^*\right]}{\left[g + n_j \beta_j \lambda_j \left(H_j/H^*\right)^{\gamma}\right]} \tag{13}$$

This ratio is increasing in the rate of entry and exit of firms in economy j, the stock of human capital in economy j and in the degree of openness of the economy regarding adoption activities and decreasing in the corresponding factors of the leading economy. The effect of the technological frontier´s growth rate is ambiguous. If the leading economy has a higher absorptive capacity than country j, then an increase in g enlarges the TFP difference between leading and non-leading economies. The contrary happens if the leading economy has worse parameters. As the non-leading economy usually exhibits worse parameters than the leader, an increase in the growth rate of the technology frontier tends to amplify the differences between leading and non-leading countries.

Empirical evaluation

Our main goal is to disentangle the relative weight of each of the four factors in explaining the existing per capita income differences. To accomplish this task, we first calibrate the parameters for the economies in the sample and then we perform some simulation exercises to study the effects of each factor on average productivity. We compare all economies to a benchmark economy: the US. Thus, TFP is measured relative to the TFP of the US in steady state. A value of 1 denotes that the country reaches the same TFP level than the US in steady state. Equivalently, a TFP gap of 0 denotes no gap with the US in steady state. Table 1 presents the country sample.

2.3 Calibration parameters

In this setup, the aggregate production function can be written as a Cobb-Douglas production function with constant returns to scale in physical capital and labor, where the capital and labor shares are assumed to be equal across countries. We assign a value of 0.35 to the capital share of output α (Gollin, 2002); 0.02 to the discount rate ρ[6], and 0.03 to the depreciation rate δ. These values are widely used in neoclassical growth models. We assume, that the growth rate of the technological frontier g is 2.2%, the average per capita US growth rate for the years 1960-2006.[7] All other parameters are country specific. Table 2 present the values for all parameters.

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 KEI indicator related to the innovation capacity of the country. The World Bank constructs various KEI indicators which measure the capacity of an economy to diffuse and produce knowledge.

The rate of creative destruction, in turn, is proxied by the entry rates of firms reported by the World Bank for the year 2005 or the data available at the nearest date. In our robustness exercise we also calibrate this variable with the exit rate of firms.

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. As for the quantity of education, we use the average years of schooling (q_j) as reported by Barro and Lee (2010). As for the quality for the education system we use the marginal return of an additional year of education of an immigrant in the US (ψ_j) as calculated by Schoellman (2010). The measure of this return in the US allows cleaning to some extent the effect of country-specific effects on returns. Nevertheless, we are

[6] Gourinchas and Parker, 2002; Cagetti, 2003; and Laibson et al. (2007) estimate discount rates for the US in the range of 0.01 to 0.09. We choose 0.02 in order to obtain a plausible risk-free interest rate.

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

aware that there may be selection bias as this variable measure only the returns of the people that left their countries. The formulation for H_j can be written as:

$$H_j = \exp(q_j \psi_j) \qquad j =, 1, 2, 3...J$$

Finally, we need an estimate for parameter γ. This parameter defines how intense the adoption activity uses human capital to copy new technologies. As there is no previous reference about the value of this parameter, we estimate the following equation by non-linear least squares. As a proxy for the technological frontier, we take the TFP level of the US.

$$A_t = A_{t-1} + \phi\lambda \ \left(h_{t-1}/h^*_{t-1}\right)^{\gamma} (A_{mt-1} - A_{t-1}) + \varepsilon_t \tag{14}$$

We use a cross section for 70 countries. Data for total factor productivity correspond to Solow residuals for the years 2004 and 2005. We estimate the previous equation with four different KEI indices that serve as proxies for the institutional environment that governs the adoption activity. We also check with different measures for human capital such as the stock resulting from education spending and a quality variable proxied by international tests. Results do not differ significantly.

	KI Innovation	KI Regulations	KI Infrastructure	KEI Global
γ	1.85***	1.47***	1.74***	1.63***
	(0.51)	(0.51)	(0.56)	(0.50)
N	70	70	70	70

Standard errors in parenthesis. *** Denote significance at 1%

Estimates fluctuate in the range 1.5-1.9. We choose the value of 1.5 for our calibrations.

3 Discussion

3.1 Calibration

In this section, we calibrate the parameters for the 33 economies to obtain the corresponding TFP values in steady state. Because of data availability, we restrict our analysis to a sample

22 developed countries and 11 developing countries. Figure 1 exhibits the distribution of the relative TFP across countries estimated by the model and the actual values of the ratio.

The mean squared error of the estimated values in the sample is 1.8%. Moreover, we perform a Kolmogorov-Smirnov test to test the null hypothesis that both series are drawn from the same distribution and we cannot reject the null hypothesis. The probability associated to the null hypothesis is 27%.

Table 3 present the TFP ("Model") implied by the model for each economy and compares them with the actual data ("Actual"). The calibrated values correspond to the calibrated TFP value of country j in steady state relative to the calibrated TFP of the US in steady state. Actual values correspond to the actual TFP ratios between country j and the US estimated as a residual from Solow regressions for each country. Note, that actual measures are not steady state values since countries are still transiting to the steady state. However, this actual measure is the best proxy that we have at hand for comparing the results of the model.

As expected, developed countries show higher TFP in steady state relative to their developing counterpart. The former group reaches in steady state an 80% of the TFP of the US, while the second group reaches a 50% of this benchmark level. Variance is also higher in this second group as country parameters are more disperse in this group. The model produces a reasonable fit of the data, which leave us confident to perform policy exercises.

As a robustness check, we compute the implied income per worker that the model produces and compares it with the actual data for per worker income. For this purpose, we re-write per capita income ratios in the following way.

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

We made the calculations with the single value of $\alpha = 1/3$ and use the K/L data from Calderón (2010). We present the results separately for developing and developed countries in tables 4 and 5. Although the implied values are more disperse than with the TFP measure, implied per capita income ratios are, in general, relatively close to the actual data.

In summary, a simple model of technological change makes a good match of the empirical distribution of relative TFP. The four factors that we identify as key variables in explaining the absorption capacity of the economies explain a large fraction of the TFP gaps across economies.

Now, the natural question is which one of these factors matters most for development in each economy. This is what we address next.

4 Disentangling TFP gaps

The main goal of this section is to identify bottlenecks that impede that economies can opt to higher per capita income through adopting better technologies. For this task, we perform two exercises that we named as i) top down and ii) bottom up, respectively. We proceed to explain both exercises and discuss the results.

4.1 Exercise 1: Top down

In this exercise, we start assuming that all economies share the same parameters as the US. As a consequence, there is no technology gap between any country and the US. Afterwards, we evaluate the impact on TFP of turning one parameter at the time to its actual level. This allows us to determine the contribution of each parameter in explaining the gap. Finally, we compute the overall effect of turning all four parameters to their actual level. In this case, we obtain the TFP gaps that were described in the previous section. We compare the sum of the individual effects with the total effect.

We present the results for developing and developed countries in figures 2 and 3, respectively. The vertical axis measures productivity gaps with the US. Each rectangle measure the contribution of each factor in explaining the current technology gap if the country had all the parameters at the US level, but the parameter that is being evaluated.

Figure 2 comprises the exercise for developing countries. For instance, in the case of Colombia (COL), one half of the technology gap between Colombia and the US is explained by a low stock of human capital. The problem is not that Colombia´s average years of schooling are so low, but that the quality of the education system, measure as the return of an additional year of schooling, is very low. The second major problem of the Colombian economy is its relatively low rate of creative destruction. In fact, the entry rate for this economy is 5% compared to the 13% in the case of the US. Another interesting result is that having all values of the parameters below the US generates an additional negative effect on the TFP gap. This is an effect due to interactions. It accounts for the fact that having all parameters at low levels at the same time produce an additional effect on the performance of the economy. For all developing countries under analysis, there is a complementary negative effect of having simultaneously all the parameters below the leader. Another intuition for this result is that policy reforms are subject to decreasing returns.

Developing countries have problems in all areas. However; if we had to make a rank, major problems would be the low quality of the education system and the low microeconomic flexibility.

The picture for the developed countries is somewhat different. Figure 3 shows the results for this group of countries. Coherent with the previous section, we see that this group shows TFP gaps that are systematically lower than the gaps of developing countries. Contrary to the case of the developing countries, we see that there are some rectangles in the negative region. This happens when the corresponding country has a better parameter compared to the US and it is mostly observed in the factor that measures the quality of the education system. For instance, Denmark is a country that has a better education system relative to the US. This better schooling environment acts as a factor that closes the TFP gap instead of opening it. Nevertheless, all countries in the sample present a positive technology gap with the US. In this case, the low microeconomic flexibility accounts for the largest fraction of the gap with the US.

As mentioned previously, the model generates a kind of complementarity among all factors. This means that the effect of one policy depends on the value of all other parameters in the model and also on the average technology gap of the country. On the one hand, this "top down" measure tends to overestimate the effect of improving a parameter, due to the high level of all other variables; but, on the other hand it tends to underestimate the effect as it considers a smaller technology gap. The latter factor tends to compensate the former one.

Although this exercise allows for a cleaner comparison across countries, when evaluating the potential effects of improving one policy parameter or variable it may be more reasonable to start with the current state of the economy. This is the second exercise that we perform.

4.1.1 Exercise 2: Bottom up

In this second exercise, we start computing the current technology gap with the US. The goal here is to quantify the effect of improving each parameter to the level of the US when maintaining the rest of the parameters at their actual level. We repeat this exercise for each factor.

Results are presented for both groups of economies in tables 6 and 7 and figures 4 and 5. Each column shows the effect on TFP gaps of turning the corresponding parameter at the level of the US, keeping the other at the country's level. Qualitatively, this bottom up evaluation provides similar implications as the top down exercise for both types of countries Results are consistent with the previous exercise. Again, developing countries show problems in all areas and mostly regarding the quality of the education system and the flexibility for entering and exiting the markets. For example, if Colombia improves these two variables simultaneously, the gap would be 80% lower. This value is obtained under the assumption that both improvements take place together. This value does not correspond to the simple addition of the effects showed in table 7, as there may be some additional effects of the interactions that have to be accounted for.

Developed countries, in contrast, are doing relatively well in all areas. The gains of improving each area are considerable lower than in the developing world. The only exception corresponds to the flexibility of the markets, where policies aiming to favor the process of creative destruction could lead to significant TFP improvements in these economies. In line with the first exercise ("top down"), we observe that several economies have better education quality than the US". Nevertheless, the contribution of education quantity and quality presents a large variance across the developed world. In terms of the institutions related to the adoption activity, we observe that these economies are relatively opened and favor technological transfers.

In summary, the developed world should continue improving the flexibility of their markets. In contrast, the case of the developing world is more dramatic, since efforts should be made in all areas. The fact that these economies have problems in almost all areas produces an additional negative effect explained by the existence of complementarities between policies.

5 Concluding remarks

Technology adoption is a key vehicle for improving productivity in the economies. This is true for developing and developed countries. However, this process is not automatic. It requires that the economies posses the capacity for absorbing and implementing the technologies developed elsewhere. We identify four factors that are essential for shaping this absorptive capacity: the stock of human capital that is determined by the quantity of education and by the quality of the educational system; the institutional environment (barriers, rule of law, property rights) that favors or hinders the adoption activity and the microeconomic flexibility that permits 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 allows resembling the distribution of TFP gaps (respect to the US) around the world. In fact, this model closely replicates the TFP distribution for developing and developed countries. It also allows us to disentangle and quantify the relative weight of these factors in explaining the TFP gap of each country with the benchmark economy.

Developing countries have problems in all areas (human capital, microeconomic flexibility and institutions pro technology adoption). That explains the enormous gap in TFP and, consequently, in per capita income with the US. It is also interesting to note that the fact that these countries have an overall a poorer environment for adoption, relatively to the US, produces an additional negative effect on the absorptive capacity of these economies. This result arises as a consequence of the complementarities that exist between the different policies in a country.

The picture is much more positive for the developed world. As a result, productivity gaps with the US are much lower. In all, problems of these countries are associated to the rigidities of their markets. Obstacles in the process of entry and exit of firms explain the largest fraction of their TFP gaps. It is also worth noting, that some of these economies tend to have better quality of education than the US, which helps them in closing the gap.

References

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

[2] Banerjee, A. and E. Duflo (2005). Growth Theory through the Lens of Development Economics.

[3] In P. Aghion and S. N. Durlauf (Eds.), Handbook of Development Economics, pp. 473–552.

[4] Elsevier B.V.

[5] Barro, Robert J., and Xavier Sala-*i*-Martin (1992). "Convergence." Journal of Political Economy, vol. 100, pages 223-51.

[6] Barro, Robert J., and Xavier Sala-*i*-Martin (1995). "Technological Diffusion, Convergence and Growth." NBER Working Paper 5151.

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

[8] Basu, Susanto and David N. Weil (1998). "Appropriate Technology and Growth." The Quarterly Journal of Economics, vol. 113, pages 1025-54.

[9] Benabou, Roland (1996). “Equity and Efficiency in Human Capital Investment: The Local Connection.” Review of Economic Studies, Blackwell Publishing, vol. 63(2), pages 237-64, April.

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

[11] Bils, M., and Klenow, P.J. (2000), “Does Schooling Cause Growth”, The American Economic Review 90(5):1160-1183.

[12] Caballero, Ricardo and Adam B. Jaffe (1993). “How High are the Giants’ Shoulders: An Empirical Assessment of Knowledge Spillovers and Creative Destruction in a Model of Economic Growth.” NBER Working Papers 4370, National Bureau of Economic Research, Inc.

[13] Calderón, C. (2010). "Measures of TFP". The World Bank.

[14] Christensen, L.R., D. Cummings, and D.W. Jorgenson (1981), “Relative Productivity Levels, 1947-1973: An International Comparison”, European Economic Review 16(1):61-94.

[15] de la Fuente, A., and R. Dom´enech (2002), “Human Capital in Growth Regressions: How Much Difference Does Data Quality Make? An Update and Further Results”, CEPR Discussion Papers No. 3587.

[16] Duflo, E. (2001), “Schooling and Labor Market Consequences of School Construction in Indonesia: Evidence from an Unusual Policy Experiment”, American Economic Review 91(4):795-813.

[17] Easterly, W., and R. Levine (2001), “It’s Not Factor Accumulation: Stylized Facts and Growth Models”, World Bank Economic Review 15(2):177-21

[18] Easterly, William and Ross Levine (2001). “It’s Not Factor Accumulation: Stylized Facts and Growth Models.” World Bank Economic Review, vol. 15, pages 177- 219.

[19] Galor, Oded (2005). “Unified Growth Theory: From Stagnation to Growth.” In Peter Aghion and Steven Durlauf (eds.) Handbook of Economic Growth (Amsterdam: North-Holland), pages 171–293.

[20] Galor, Oded, Omer Moav,and Dietriech Vollrath (2008). “Inequality in Land Ownership, the Emergence of Human Capital Promoting Institutions and the Great Divergence.” CEPR Discussion Papers 6751.

[21] Galor, Oded and Joseph Zeira (1993). "Income Distribution and Macroeconomics." Review of Economic Studies, vol. 60(1), pages 35-52.

[22] Gerschenkron, Alexander (1952). "Economic Backwardness in Historical Perspective." In The Progress of Underdeveloped Areas, edited by Bert Hoselitz. Chicago. University of Chicago Press.

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

[24] Grossman, Gene and Elhanan Helpman (1991). Innovation and Growth in the Global Economy. The MIT Press.

[25] Hall, Robert E. (1998). "Intertemporal Substitution in Consumption." Journal of Political Economy, vol. 96, pages 339-357.

[26] 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.

[27] Hanushek E.A., and D.D. Kimko (2000), "Schooling, Labor-Force Quality, and the Growth of Nations", The American Economic Review 90(5):1184-1208.

[28] Hanushek, E.A. (2004): "Some Simple Analytics of School Quality," NBER WP 10229.

[29] Helpman, Elhanan (1993). "Innovation, Imitation, and Intellectual Property Rights." Econometrica, vol. 61(6), pages1247-1280.

[30] Hopenhayn, H. A. (1992). "Entry, exit, and Firm dynamics in long run equilibrium". Econometrica, 60(5): pages 1127-1150, September.

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

[32] Howitt, Peter and David Mayer-Foulkes (2005). "R&D, Implementation and Stagnation: A Schumpeterian Theory of Convergence Clubs." Journal of Money Credit and Banking, vol. 37, pages 147–177.

[33] Hsieh, C.-T. (2000), "Measuring Biased Technology", Working Paper (Princeton University).

[34] Islam, N. (1995), "Growth Empirics: A Panel Data Approach", The Quarterly Journal of Economics 110:1127-1170.

[35] Johnson, G.E., and F.P. Stafford (1973), "Social Returns to Quantity and Quality of Schooling", Journal of Human Resources 8(2):139-155.

[36] 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.

[37] Knight, M., N. Loyaza, and D. Villanueva (1993), "Testing the Neoclassical Theory of Economic Growth", IMF Staff Papers 40(3):512-541

[38] Laibson, David, Andrea Repetto, and Jeremy Tobacman (2007). "Estimating Discount Functions with Consumption Choices over the Lifecycle." Economics Series Working Papers 341, University of Oxford, Department of Economics.

[39] Lederman, Daniel and Laura Saenz (2005). "Innovation and Development Around the World, 1960-2000." Policy Research Working Paper Series 3774, The World Bank.

[40] Lucas, Robert E. Jr. (2000). "Some Macroeconomics for the 21st Century." Journal of Economic Perspective, vol. 14, pages 159-68.

[41] Lutz, H. (2002), "How Important Is Human Capital for Development? Evidence from Immigrant Earnings", American Economic Review 92(1):198-219.

[42] Maddison, Angus (1999). Statistics on World Population, GDP and Per Capita GDP, 1-2006 AD.

[43] Mankiw, Gregory, David Romer, and David Weil (1992). "A Contribution to the Empirics of Economic Growth." Quarterly Journal of Economics, vol. 107, pages 407-37.

[44] Mies, V. (2010). "Technology Adoption and Knowledge Dynamics: Consequences for Long-Run Prospects". Working Paper. Pontificia Universidad Católica de Chile.

[45] Musgrave John. (1992). "Fixed Reproducible Tangible Wealth in the United States, Revised Estimates." Survey of Current Business, vol. 72, pages 106-119.

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

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

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

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

[50] Restuccia, D., D.T. Yang, and X. Zhu (2003), "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis", Working Paper (University of Toronto, Economics Department).

[51] Schoellman, T. (2010). "The Occupations and Human Capital of U.S. Immigrants," Journal of Human Capital, University of Chicago Press, vol. 4(1), pages 1-34.

[52] Wilson, D.J. (2004), "Cross-Country Differences in Capital Composition", forthcoming in FRBSF Economic Letter.

Developed Countries	Developing Countries
Australia	Argentina
Austria	Bulgary
Belgium	Brazil
Canada	Chile
Denmark	Colombia
Finland	Czech Republic
France	Hungary
Greece	India
Ireland	Israel
Island	Mexico
Italy	Polonia
Japan	Romania
The Netherlands	Slovak
New Zealand	Slovenia
Portugal	
Sweden	
Switzerland	
UK	
USA	

Table 1: Country Sample

Country	KEI	KI Ir	KI Innov	KI Ed	kI Ict	Entry	Exit	Returns	Years School
ARG	0.632	0.308	0.774	0.760	0.675	0.092	0.055	0.063	9.346
BGR	0.756	0.790	0.613	0.875	0.763	0.127	0.001	0.049	9.851
BRA	0.683	0.477	0.854	0.689	0.694	0.087	0.034	0.047	7.539
CHL	0.780	0.969	0.703	0.741	0.710	0.111	0.072	0.055	10.183
COL	0.577	0.472	0.625	0.582	0.623	0.054	0.093	0.025	7.694
CZE	0.864	0.904	0.754	0.942	0.872	0.061	0.011	0.046	12.130
GRC	0.804	0.754	0.747	0.939	0.786	0.054	0.054	0.040	10.677
HUN	0.866	0.924	0.792	0.884	0.872	0.092	0.033	0.091	11.651
IND	0.454	0.387	0.840	0.253	0.282	0.053	-0.019	0.067	6.242
MEX	0.636	0.560	0.776	0.558	0.630	0.071	0.071	0.009	9.113
POL	0.839	0.827	0.812	0.918	0.803	0.047	0.025	0.031	9.872
ROM	0.728	0.772	0.664	0.740	0.742	0.111	0.011	0.049	10.372
SVK	0.800	0.861	0.627	0.831	0.900	0.120	0.033	0.073	11.153
SVN	0.850	0.896	0.682	0.951	0.892	0.088	0.042	0.072	8.928
AUS	0.987	0.958	0.913	1.109	0.982	0.143	0.121	0.080	12.119
AUT	0.960	1.030	0.847	0.970	1.002	0.051	0.020	0.049	9.539
BEL	0.956	0.981	0.873	1.046	0.934	0.074	0.031	0.098	10.545
CAN	1.005	1.045	0.956	1.059	0.967	0.067	0.067	0.087	11.372
CHE	0.962	0.972	0.903	0.879	1.096	0.062	0.047	0.098	9.876
DNK	1.016	1.063	0.859	1.119	1.043	0.133	0.045	0.069	10.057
FIN	0.996	1.030	0.864	1.118	0.989	0.078	0.054	0.057	9.974
FRA	0.943	0.848	0.958	1.032	0.935	0.105	0.070	0.077	10.533
GBR	1.010	1.022	0.978	0.971	1.070	0.154	0.088	0.098	9.593
IRL	0.974	1.024	0.853	1.046	0.986	0.107	0.087	0.072	11.640
ISL	0.894	1.055	0.496	1.077	0.997	0.116	-0.009	0.071	10.734
ISR	0.851	0.912	0.854	0.785	0.854	0.121	0.094	0.075	11.325
ITA	0.884	0.732	0.921	0.911	0.973	0.127	0.080	0.039	9.506
JPN	0.940	0.864	0.993	0.992	0.906	0.044	0.036	0.106	11.582
NLD	1.016	1.020	0.927	1.054	1.078	0.113	0.070	0.095	11.023
NZL	0.951	0.972	0.776	1.119	0.958	0.163	0.052	0.091	12.695
PRT	0.823	0.931	0.707	0.795	0.867	0.064	-0.037	0.019	7.993
SWE	1.022	1.032	0.912	1.063	1.094	0.068	0.047	0.114	11.567
USA	1.000	1.000	1.000	1.000	1.000	0.131	0.111	0.093	12.201

Table 2: Parameters

Developed countries			Developing countries		
Country	**Model**	**Actual**	**Country**	**Model**	**Actual**
AUS	0.961	0.800	ARG	0.685	0.563
AUT	0.487	0.826	BGR	0.666	0.604
BEL	0.836	0.854	BRA	0.595	0.397
CAN	0.816	0.785	CHL	0.700	0.628
CHE	0.777	0.697	COL	0.315	0.391
DNK	0.849	0.810	CZE	0.545	0.589
FIN	0.661	0.740	GRC	0.450	0.631
FRA	0.860	0.837	HUN	0.874	0.636
GBR	0.977	0.853	IND	0.479	0.333
IRL	0.848	0.976	MEX	0.398	0.471
ISL	0.700	0.770	POL	0.387	0.488
ISR	0.880	0.803	ROM	0.660	0.387
ITA	0.733	0.789	SVK	0.791	0.494
JPN	0.809	0.662	SVN	0.659	0.695
NLD	0.941	0.770			
NZL	0.999	0.694			
PRT	0.372	0.575			
SWE	0.920	0.820			

Table 3: Model vs Actual

Country	TFP ratio	K/Y ratio w/r US	Implied Y/L ratio w/r US	Actual Y/L ratio w/r US	Implied/Actual
ARG	0.685	0.743	0.580	0.359	1.613
BGR	0.666	0.468	0.435	0.315	1.379
BRA	0.595	0.799	0.524	0.220	2.387
CHL	0.700	0.869	0.647	0.460	1.408
COL	0.315	0.551	0.226	0.177	1.272
CZE	0.545	0.992	0.542	0.447	1.214
GRC	0.450	1.098	0.474	0.522	0.908
HUN	0.874	0.922	0.834	0.483	1.729
IND	0.479	0.426	0.296	0.122	2.432
MEX	0.398	0.858	0.365	0.295	1.239
POL	0.387	0.894	0.364	0.318	1.143
ROM	0.660	0.796	0.581	0.211	2.753
SVK	0.791	0.995	0.789	0.342	2.304
SVN	0.659	0.989	0.655	0.573	1.144

Table 4: Implied (calibrated) and actual GDP per worker, developing countries

Country	TFP ratio	K/Y ratio w/r US	Implied Y/L ratio w/r US	Actual Y/L ratio w/r US	Implied/Actual
AUS	0.961	1.193	0.961	0.781	1.230
AUT	0.487	1.211	0.487	0.827	0.589
BEL	0.836	1.172	0.836	0.855	0.978
CAN	0.816	1.157	0.816	0.748	1.092
CHE	0.777	1.543	0.777	0.724	1.073
DNK	0.849	1.177	0.849	0.790	1.075
FIN	0.661	1.230	0.661	0.706	0.937
FRA	0.860	1.190	0.860	0.835	1.030
GBR	0.977	0.912	0.977	0.750	1.303
IRL	0.848	0.798	0.848	0.858	0.988
ISL	0.700	1.076	0.700	0.698	1.003
ISR	0.880	1.037	0.880	0.731	1.205
ITA	0.733	1.209	0.733	0.771	0.951
JPN	0.809	1.591	0.809	0.681	1.189
NLD	0.941	1.132	0.941	0.718	1.311
NZL	0.999	1.091	0.999	0.602	1.659
PRT	0.372	1.134	0.372	0.461	0.806
SWE	0.920	1.042	0.920	0.756	1.217

Figure 1: Table 5: Implied (calibrated) and actual GDP per worker, developed countries

	Years school	Quality	Flex.	Institution
ARG	0.074	0.113	0.097	0.071
BGR	0.049	0.172	0.009	0.133
BRA	0.095	0.148	0.119	0.046
CHL	0.046	0.150	0.045	0.095
COL	0.040	0.208	0.239	0.119
CZE	0.001	0.241	0.219	0.082
GRC	0.026	0.244	0.257	0.083
HUN	0.016	0.008	0.070	0.048
IND	0.173	0.070	0.257	0.050
MEX	0.011	0.326	0.171	0.069
POL	0.029	0.260	0.292	0.056
ROM	0.038	0.181	0.048	0.113
SVK	0.029	0.080	0.024	0.108
SVN	0.098	0.079	0.112	0.106

Table 6: Bottom Up, developing countries

	Years school	Quality	Flex.	Institution
AUS	0.002	0.037	-0.015	0.015
AUT	0.056	0.182	0.271	0.048
BEL	0.055	-0.019	0.118	0.031
CAN	0.026	0.025	0.142	0.011
CHE	0.083	-0.020	0.165	0.026
DNK	0.049	0.077	-0.002	0.034
FIN	0.054	0.146	0.142	0.041
FRA	0.042	0.054	0.049	0.010
GBR	0.054	-0.012	-0.027	0.004
IRL	0.014	0.078	0.045	0.036
ISL	0.043	0.095	0.033	0.177
ISR	0.021	0.061	0.017	0.033
ITA	0.042	0.183	0.008	0.022
JPN	0.024	-0.058	0.209	0.002
NLD	0.029	-0.006	0.027	0.014
NZL	#####	0.005	-0.034	0.034
PRT	0.031	0.249	0.201	0.093
SWE	0.021	-0.079	0.105	0.018

Table 7: Bottom Up, developed countries

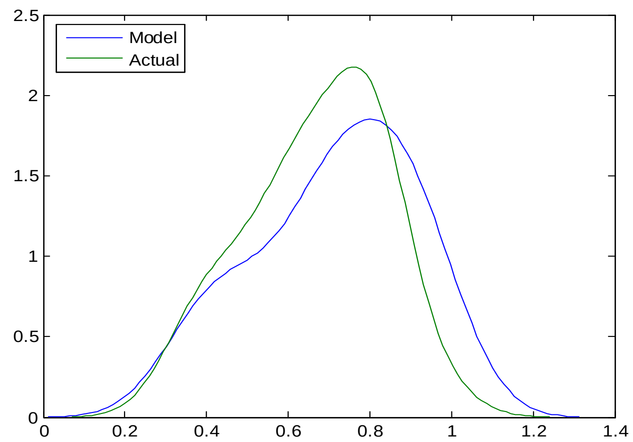

Figure 1: Actual vs Model

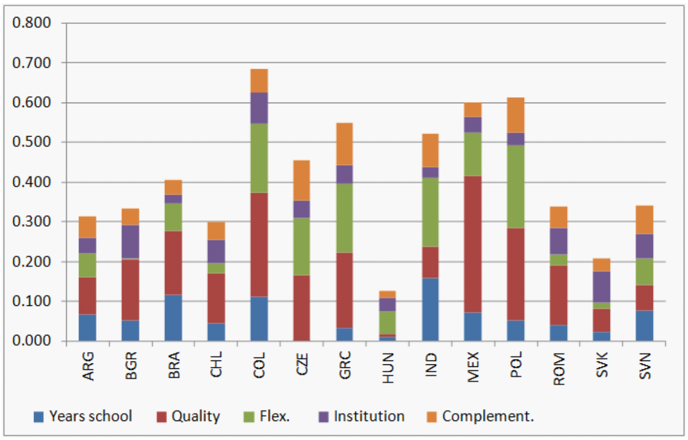

Figure 2: Top Down, developing countries

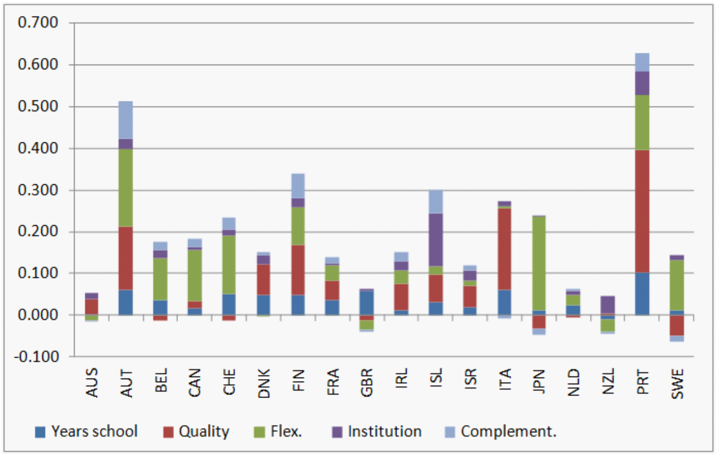

Figure 3: Top Down, developed countries

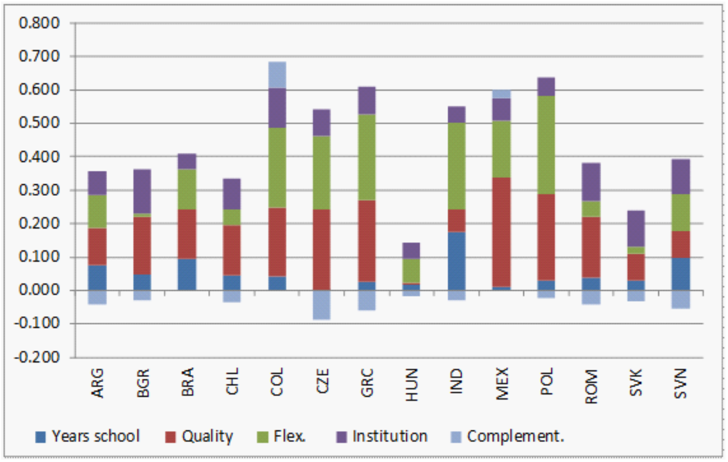

Figure 4: Bottom up, developing countries

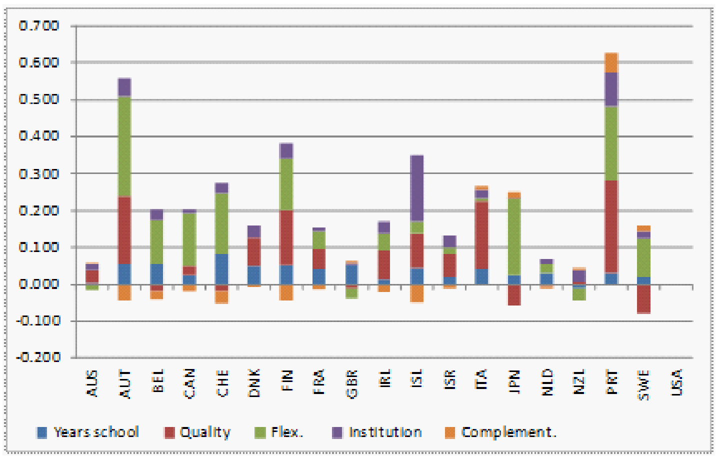

Figure 5: Bottom up, developed countries