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A New Proposal to Model the Relationships between Total Factor Productivity, Institutions and Accumulation

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ABSTRACT

In this paper, we discuss the relationship between Total Factor Productivity (TFP), accumulation and institutions. In order to show these connections, a new model is presented that is able to shed some light on the links involving this multi-dimensional relationship, which goes from countries' quality of institutions to their stocks of physical and human capital and from these to TFP. The model is constructed in analogy with the physical law of thermal expansion and it introduces a new parameter that measures the response of TPF to variations in stocks of capital, in relation to institutional quality. Thanks to the proposed model, an operational methodology of such a parameter is defined (based on certain macroeconomic variables) and an estimate of it is provided (on the basis of a time series relative to a wide range of countries).

Keywords: Growth, Total Factor Productivity, Accumulation Processes, Institutions
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1. INTRODUCTION

In the economic literature of the past decades, contributors often aimed at researching determinants of growth, setting accumulation processes against the Total Factor Productivity (TFP). Against this general approach, the idea that motivates our study is that the contrast between accumulation and TFP is actually an oversimplification of reality. In fact, the process of economic growth is the result of a complex combination of factors interacting in different ways. In this dimension, it is not sufficient to determine whether or not TFP is the main driver of growth. Instead, we should return to examine the system of relations binding the productive factors. It is the search for this system of relations that constitutes the motivation for the present work.

In fact, economic literature already offers insight on the links between individual accumulation factors and TFP, yet a systemic view of these connections is still poorly analyzed.

Wolff (1991), for example, stressed that technological level is positively associated with the growth rate of physical capital per worker, despite the strength of this association's great variations over time. In particular, Wolff writes, the association between technology and capital is significantly reduced when economic systems present obstacles to economic growth or when differences between countries in technological levels are very low. However, the hypothesis that investment in physical capital is unable to increase TFP was already present in the work of Abramovitz (1986), who emphasized the existence of a strong relationship between TFP and "social capacity" of absorbing new technologies. Here, "capacity" is linked both to the quality of institutions and to the educational level of the population. Also in Hall and Jones (1999), capital accumulation and technology are related to "social infrastructure," understood as institutions and government policies. "Infrastructure" is thus defined as able to generate more or less favorable economic environment for development, within which individuals accumulate skills and companies accrue capital. More recently, Papageorgiou and Chmelarova (2005) record evidence for a relationship of complementarity between physical and human capital, which nevertheless has the characteristics of non-linearity. Although this complementarity is indeed significant (albeit not constant over time) in delayed economic development countries, it disappears in most industrialized countries in favor of a stronger link between human capital and technology.

In this paper, we verify the existence and measure the intensity of the relationship between accumulation factors and TFP, taking into account the role played by institutions. In fact, institutions can deeply affect both direction and intensity of such relationships, due to their pervasive effect on the economic environment. The available information on the quality of institutions gives us the possibility to analyze 121 countries (listed in Annex Table 1) from 1985 to 2009.

The paper is organized as follows. First, we present a model of conditional convergence in TFP.

In the subsequent chapters, we discuss the econometric technique used to estimate the model's parameters and describe data used in the analysis. Finally, we present and discuss the results obtained in order to identify the existence of a network of relationships.

2. MODEL

The working hypothesis of this article, inspired by Nelson and Phelps (1966), is that TFP growth rate in each country is positively correlated to the difference between current level of TFP and its potential value. In mathematical form:

$$\frac{d}{dt}\log A(t) = \lambda\left(\log A^*(t) - \log A(t)\right), \tag{1}$$

Where, *A(t)* is the TFP of a specific country, at a given period, *A*(t)* is the "potential" TFP for this country in the same period, and λ is related to the conditional convergence coefficient. The "potential" TFP is assumed depending explicitly on the stock of physical and human capital (*k* and *h* respectively) and only implicitly on time, by means of a function *T(t)*, representing the exogenous growth index of the technological frontier. So, in the following, the "potential" TFP will be denoted $A^*(h,k)$.

In other models, see for example Aiyar and Feyrer (2002), the relationship between the potential TFP and capital, physical or human, is characterized by a constant elasticity. That is, named ε_{A^*k} and ε_{A^*h}, the elasticities with respect to physical and the human capital, respectively, defined as: $\varepsilon_{A^*k} = \frac{\partial A^*(h,k)}{\partial k}\cdot\frac{k}{A^*}$, $\varepsilon_{A^*h} = \frac{\partial A^*(h,k)}{\partial h}\cdot\frac{h}{A^*}$ are constant.

The elasticity of an economical variable, for example $A^*(h,k)$, with respect to another variable, for example *h*, is an useful *a*-dimensional parameter to express the responsiveness of the potential TFP with respect any change of human capital, in terms of percentage changes, that is:

$$\varepsilon_{A^*h} = \frac{\Delta A^*}{A^*} \bigg/ \frac{\Delta h}{h}$$

If this parameter is constant, as is the case in the work of Aiyar and Feyer (2002) where it is indicated with the letter φ, it is possible to suppose the following relationship between the potential TFP and human capital:

$$A^*(t) = Fh^{\varphi}T(t)$$

In this work a new model will be discussed in which the elasticities of $A^*(h,k)$, defined above, are no longer constants, but depend on the country's quality of institutions, measured through a composite index (*I*) varying between 0 and 100.

When the responsiveness of the "potential" TFP to physical capital is deemed, now expressed by $\varepsilon_{A^*h}(I)$, the following linear relation is supposed:

$$\frac{\Delta\varepsilon_{A^*h}(I)}{\varepsilon_{A^*h}(I)} = \varphi_h \Delta I$$

Similarly for the responsiveness with respect to *k*:

$$\frac{\Delta\varepsilon_{A^*k}(I)}{\varepsilon_{A^*k}(I)} = \varphi_k \Delta I$$

These relationships are the mathematical translation of the simple law that the fractional change of elasticity is a linear function of the change in the quality of institution index. For each unitary change of the index *I* the elasticity changes of φ_h, or φ_k, units. These two new parameters have the important role of describing the way in which the economic system is able to react to any change in the quality of institutions, in other words they express how changes in the quality of institutions affect the responsiveness of the "potential" TFP to human and physical capital.

It is also interesting to note that these relationships are similar to the linear approximation law for thermal expansion for solid materials. In this analogy, the quality of the institutions, *I*, plays the role of temperature, and the elasticity is similar to the physical dimension under examination (i.e., length, area, or volume), and the constants φ_h and φ_k correspond to the "thermal expansion coefficient."

If the value zero of the index *I* is taken as the reference level, we indicate with θ and ω the value of elasticity corresponding to this reference level, with respect to physical and human capital, respectively. Therefore:

$\varepsilon_{A^*k}(I = 0) = \theta$,

$\varepsilon_{A^*h}(I = 0) = \omega$.

If ΔI represents the variation between the reference level, $I = 0$, we obtain that $\Delta I = I - 0 = I$, and,

$\Delta\varepsilon_{A^*k} = \varepsilon_{A^*k}(I) - \varepsilon_{A^*k}(I = 0) = \varepsilon_{A^*k}(I) - \theta$;

$\Delta\varepsilon_{A^*h} = \varepsilon_{A^*h}(I) - \varepsilon_{A^*h}(I = 0) = \varepsilon_{A^*h}(I) - \omega$.

So, one obtains:

$$\frac{\Delta\varepsilon_{A^*k}}{\theta\varepsilon_{A^*k}(I=0)} = \varphi_k I \Rightarrow \frac{\varepsilon_{A^*k}(I)-\theta}{\theta} = \varphi_k I \Rightarrow$$
$$\varepsilon_{A^*k}(I) = \theta(1+\varphi_k I);$$

$$\frac{\Delta \varepsilon_{A^*h}}{\omega \varepsilon_{A^*h}(I=0)} = \varphi_h I \Rightarrow \frac{\varepsilon_{A^*h}(I)-\omega}{\omega} = \varphi_h I \Rightarrow$$
$$\varepsilon_{A^*h}(I) = \omega(1+\varphi_h I).$$

These new expressions for elasticity permit to assume:

$$A^*(t) = k^{\theta(1+\phi_k I)} h^{\omega(1+\phi_h I)} T(t) \quad (2)$$

As previously affirmed, the two coefficients, φ_k and φ_h, if correctly estimated, will be able to describe how the quality of institutions can modify the force and direction of the relation between capitals and TFP, in each single country, then they are a sort of thermal coefficient, here called "coefficients of institutional variation," for the elasticity of TFP. Moreover, to take into account technological progress throughout the world, the "potential" TFP is also positively related to an exogenous index *T(t)*, representing the growth rate for the technological frontier.

As can be seen, when the quality of institutions is excluded from calculation, the equation (2) returns a classic Cobb-Douglas, in which stocks of physical and human capital constitute the production factors of TFP. The underlying idea is that physical and human capital represent the generative elements of competition, from which incentives for innovative activity are formed, as well as the circulation of information flows and the use of new imported technologies.

The idea that human capital affects TFP belongs to a long standing scholarly tradition that dates back to the contribution of Nelson and Phelps (1966). Empirical evidence of the comparative advantage of higher education levels among workers on innovation was obtained by Wozniak (1984), Bartel and Lichtenberg (1987), Foster and Rosenzweig (1995). Other interesting contributions were made by Benhabib and Speigel (1994), Bils and Klenow (2000). They suggest that the relationship between human capital and economic growth can be better observed in relation to the positive effects of human capital on TFP, rather than through its direct effects (as productive factor) on the production function. The idea that physical capital may affect TFP growth rate is related, on the other hand, to the contributions of Abramovitz (1979), Wolff (1991), Klenow and Rodriguez-Clare (1997), Basu and Weil (1998). While they accept the existence of a functional link between physical capital and TFP, they do not agree on the direction and intensity of this link. For example, in quite a counterintuitive way, Klenow and Rodriguez-Clare record an inverse relation between physical capital and TFP. They explain it as a consequence of inefficient accumulation of physical capital in the public sector.

The insertion of the quality of institutions in equation (2) modifies the reactivity according to which factors of accumulation contribute to the variation of TFP. The underlying idea is that institutions act at the heart of the market system, affecting competition between agents and giving form to the structure of individual incentives towards innovation, to the circulation of information, to the adoption of new technologies. A variation in the institutional framework is thus capable of impacting the elasticity of the TFP with respect to factors of accumulation. Let us hypothesize, for instance, an increase in the levels of corruption of public institutions and of the judicial system. In such a situation, competition between agents would be negatively compromised, in favor of an increase of transition costs. To make any form of exchange possible (related to flows of information or new technologies), agents will be obliged to compensate for increased transition costs, using previously accumulated resources (be these physical or human capital). Thus, at the same intensity of the accumulation process, only a small quantity of physical and human capital could impact on the variation of TFP.

A similar effect would be produced in the case of a weakening of actions contrasting monopolies, the formation of cartels or the acquisition of economic rents. In these cases, businesses already present on the market would see strong incentives in the creation of barriers to entry and innovation. But the creation of barriers requires resources, both with respect to their maintenance and to attempts to overcome them, with the consequence that in processes of accumulation of similar intensity only a small quantity of physical and human capital can be targetted towards TFP. In all these cases, the elasticity of TFP in relation to accumulation factors would be mitigated.

On the other hand, improvements in the institutional framework would favor the growth process of TFP. Let us consider, for instance, a strong cultural opposition to corruption. In these circumstances, the capacity of markets to work effectively would be enhanced by the compression of corruption costs (costs payed in the form of bribes), new resources would be unleashed from the system of illicit division and appropriation, and new unexpressed potentialities would be activated from factors of accumulation that were previously suffocated by the system of reciprocal favoritism. Keeping the intensity of the process of accumulation constant, thus, an increased quantity of resources and an improved quality of energy may be used in favor of TFP. The elasticity of TFP in relation to accumulation factors would thus be amplified.

Despite the existence of a wide range of literature around institutions (North and Thomas, 1973; North, 1981; 1990; Greif, 1993; Engerman and Sokoloff, 1997; La Porta et al., 1998; Hall and Jones, 1999; Acemoglu et al., 2001; 2005; Djankov et al., 2002; Glaeser and Shleifer, 2002; Gradstein, 2002; 2004; Acemoglu et al., 2001), only few scientific contributions focus on to the ability of institutions to condition productivity levels. As pointed out by Sala-i-Martin (2002), "we are still in the early stages when it comes to incorporating institutions into our growth theories." The same position was expressed by Helpman (2004), attempted to identify original elements emerging in recent literature. The observed differences in paths of economic growth could be explained in Helpman's opinion through differences in institutional structures. These differences affect the incentives to innovate, develop new technologies, reorganize production, and accumulate physical and human capital. The particular relationship between institutions and incentives to innovate was developed by Tebaldi and Emslie (2008). According to them, quality of institutions affects the ability of human capital to expand the technological frontier. The quality of institutions can retard or stimulate the introduction of new technologies; so it is intrinsically linked to the long-run growth rate of the economy. Recently, Acemoglu and Robinson (2012) provide new consideration about institutions and growth. Through a broad multiplicity of historical examples, they argue that nations thrive when they develop "inclusive" institutions, able to enforce property rights, create a level playing field, and encourage investments in new technologies and skills. Conversely, nations fail when those institutions become "extractive" and concentrate power and opportunity in the hands of only a few.

As may be evident, on the basis of our overall observations, equation (2) aims at synthesizing the different approaches, developed at different times and in different contexts; it tries, in other words, to achieve a synthesis of the economic literature.

Back to the model: After taking the logarithm of $A^*(t)$, it is possible to rephrase the equation (1) as follows:

$$\frac{d}{dt}\ln A = \lambda\left(\theta \ln k + \omega \ln h + \theta\phi_k I \ln k + \omega\phi_h I \ln h + \ln T(t)\right)$$
$$-\lambda \ln A(t).$$

Multiplying both sides of this equation by $e^{\lambda t}$ and rearranging terms, we have:

$$e^{\lambda t}\left[\frac{d}{dt}\ln A + \lambda \ln A(t)\right] = e^{\lambda t}\lambda$$
$$\left(\theta \ln k + \omega \ln h + \theta\phi_k I \ln k + \omega\phi_h I \ln h + \ln T(t)\right).$$

Integrating on the temporal interval $[t_1,t_2]$, we have:

$$\int_{t_1}^{t_2} e^{\lambda t}\left[\frac{d}{dt}\ln A + \lambda \ln A(t)\right]dt = \int_{t_1}^{t_2} e^{\lambda t}\lambda\theta \ln k dt$$
$$+\int_{t_1}^{t_2} e^{\lambda t}\lambda\omega \ln h dt + \int_{t_1}^{t_2} e^{\lambda t}\lambda\theta\phi_k I \ln k dt +$$
$$+\int_{t_1}^{t_2} e^{\lambda t}\lambda\omega\phi_h I \ln h dt + \int_{t_1}^{t_2} e^{\lambda t}\lambda \ln T(t)dt.$$

Considering the variables h, k and I constants into the integration interval, the result of integration is:

$$e^{\lambda t_2}\ln A(t_2) - e^{\lambda t_1}\ln A(t_1) = \theta \ln k\left(e^{\lambda t_2} - e^{\lambda t_1}\right) +$$
$$\omega \ln h\left(e^{\lambda t_2} - e^{\lambda t_1}\right) + \theta\phi_k I \ln k\left(e^{\lambda t_2} - e^{\lambda t_1}\right) + \omega\phi_h I$$
$$\ln h\left(e^{\lambda t_2} - e^{\lambda t_1}\right) + \int_{t_1}^{t_2} e^{\lambda t}\lambda \ln T(t)dt$$

The assumption used for the integration is quite common in panel estimates on growth. For example, Islam (1995) and Caselli et al. (1996) assume that the independent variables in their models (i.e., savings rate, population growth rate, and stock of human capital) are constant over 5 years.

Finally, multiplying the above equation by $e^{-\lambda t_2}$, we can write:

$$\ln A(t_2) - e^{-\lambda\tau}\ln A(t_1) = \theta\left(1 - e^{-\lambda\tau}\right)$$
$$\ln k + \omega\left(1 - e^{-\lambda\tau}\right)\ln h + \theta\phi_k I\left(1 - e^{-\lambda\tau}\right)\ln k + \omega\phi_h$$
$$I\left(1 - e^{-\lambda\tau}\right)\ln h + \lambda e^{-\lambda t_2}\int_{t_1}^{t_2} e^{\lambda t}\ln T(t)dt \qquad (3)$$

Where, τ is equal to (t_2-t_1).

Then, it is possible to redefine the individual components of the equation (3) as follows:

$a_{i,t} = \ln A(t_2)$,

$\rho = e^{-\lambda\tau}$,

$a_{i,t-1} = \ln A(t_1)$,

$\beta_1 = \theta\ (1-e^{-\lambda\tau})$,

$z_{i,t-1} = \ln k(t_1)$,

$\beta_2 = \omega\ (1-e^{-\lambda\tau})$,

$x_{i,t-1} = \ln h(t_1)$,

$w_{i,t-1}\ I(t_1)$,

$$\eta_t = \lambda e^{-\lambda t_2}\int_{t_1}^{t_2} e^{\lambda t}\ln T(t)dt,$$

$\beta_3 = \varphi_k\beta_1$,

$\beta_4 = \varphi_h\beta_2$.

Moreover, adding the error term, we can write:

$$a_{i,t} = \rho a_{i,t-1} + \beta_1 z_{i,t-1} + \beta_2 x_{i,t-1} + \beta_3 w_{i,t-1}z_{i,t-1} + \beta_4 w_{i,t-1}x_{i,t-1} + \eta_t + u_{i,t} \qquad (4)$$

To estimate it, it is necessary to implement a transformation. In fact, it is necessary to eliminate the time varying component and to measure all variables as deviations from the means. In other words, new variables are defined:

$$\hat{a}_{i,t} = a_{i,t} - \frac{\sum_{i=1}^{N} a_{i,t}}{N}$$

$$\hat{a}_{i,t-1} = a_{i,t-1} - \frac{\sum_{i=1}^{N} a_{i,t-1}}{N}$$

$$\hat{z}_{i,t-1} = z_{i,t-1} - \frac{\sum_{i=1}^{N} z_{i,t-1}}{N}$$

$$\hat{x}_{i,t-1} = x_{i,t-1} - \frac{\sum_{i=1}^{N} x_{i,t-1}}{N}$$

$$\hat{w}_{i,t-1} = w_{i,t-1} - \frac{\sum_{i=1}^{N} w_{i,t-1}}{N}$$

$$\hat{\eta}_t = 0$$

$$\widehat{u}_{i,t} = u_{i,t} - \frac{\sum_{i=1}^{N} u_{i,t}}{N}$$

Therefore, using these variables the equation is:

$$\hat{a}_{i,t} = \rho\hat{a}_{i,t-1} + \beta_1\hat{z}_{i,t-1} + \beta_2\hat{x}_{i,t-1} + \beta_3\hat{w}_{i,t-1}\hat{z}_{i,t-1} + \beta_4\hat{w}_{i,t-1}\hat{x}_{i,t-1} + \widehat{u}_{i,t} \quad (5)$$

On its basis we can calculate the physical capital elasticity of TFP, the human capital elasticity of TFP, the "coefficients of institutional variation" and the coefficient of conditional convergence. In particular, we obtain these values as follows:

$$\lambda = -\frac{\ln\rho}{\tau}$$

$$\theta = \frac{\beta_1}{1-\rho}$$

$$\omega = \frac{\beta_2}{1-\rho}$$

$$\phi_k = \frac{\beta_3}{\beta_1}$$

$$\phi_h = \frac{\beta_4}{\beta_2}$$

3. DATA

In order to estimate equation (5), data on physical capital, human capital, number of employees, TFP and quality of institutions are required.

To calculate the physical capital stock of the 121 observed countries, we used the perpetual inventory method. It assumes that the stock of physical capital (K) in a given year equals the capital stock of the previous year, net of the depreciation rate (δ), plus the investment (I) of the current year. A key question in the application of this method is the determination of the stock of physical capital at the initial year (year zero). To solve this problem, we followed the method applied by Harberger (1978). The investment data were taken from the National Accounts Main Aggregates Database of United Nations (in U.S. dollars and constant prices 2005).

We calculate the stock of human capital, instead, as the product of the number of workers and the average level of human capital. In order to calculate this average level of human capital, we followed Hall's and Jones's suggestion (1999). They combined the average years of schooling with the average rate of schooling return into a specific functional form. This form is able to return percentage changes of human capital as percentage differences of wages for different education levels. In order to implement this approach, we used average years of schooling data published by Barro and Lee (2000) and average rate of schooling return by Psacharopulos (1994) equal to 0.134, for the first 4 years of schooling; 0.101, for the second 4 years of schooling; and 0.068, for more than 8 years of schooling.

The time series of workers for the 121 observed countries, were obtained from the Total Economy Database (the Conference Board and Groningen Growth and Development Centre) and integrated with the data of the International Labour Office.

The TFP was estimated using the following formula:

$$\ln A = \ln y - \alpha \ln k - (1-\alpha) \ln h$$

Where, A is TFP, y is the gross domestic product (GDP) per worker, α is the relative contribution of physical capital to production, k is the stock of physical capital per worker, and h is the stock of human capital per worker. In particular, the relative contribution of physical capital to production was fixed at 0.3 and 0.4, which are the range normally used on growth accounting studies (Hall and Jones, 1999; Easterly and Levine, 2001; McQuinn and Whelan, 2007; Pipitone, 2009).

To measure the quality of institutions we used data from the International Country Risk Guide. Following the contribution of Knack and Keefer (1995), four specific variables were combined: Legal system, government corruption, the quality of bureaucracy, and the risk of private investment expropriation. The combination of the four variables in an average value returns an indicator narrowly defined of the quality of economic institutions, that for simplicity we will define the "Knack-Keefer index." The use of this indicator has the objective of concentrating attention only on the variables of the institutional framework that have had a more direct impact on the functioning of markets and on the formation of individual incentives, in such a way as to eliminate possible "background noise" that could hide the deeper link between institutions, processes of accumulation and TFP. This choice has reliable precedents in specialized economic literature, for instance the contribution of Barro (1996), Sachs and Warner (1997), Hall and Jones (1999), Acemoglu et al. (2001). Moreover, the approach used coincides with Xavier Sala-i-Martin's pragmatic conceptualization of institutions (2002), which suggests considering institutions as a set of elements linked to the way in which society and the economy operate in a modern capitalist system. In this sense, Sala-i-Martin focuses his attention on the opportunities of society and the economy to enforce contracts, protect property rights, control corruption, as well as provide a transparent government and an efficient legal system.

4. ESTIMATION PROCEDURES

According to the procedure described in the previous sections, we obtained the following equation to estimate:

$$\hat{a}_{i,t} = \rho\hat{a}_{i,t-1} + \beta_1\hat{z}_{i,t-1} + \beta_2\hat{x}_{i,t-1} + \beta_3\hat{w}_{i,t-1}\hat{z}_{i,t-1} + \beta_4\hat{w}_{i,t-1}\hat{x}_{i,t-1} + \hat{\varepsilon}_{i,t}$$

This equation takes into account the two-dimensional nature of the data (time series and cross-sectional data); it presents the lagged dependent variable among the explanatory variables and contains a potential problem of endogeneity of the explanatory variables. These distinctive features allow us to configure the equation in the class of the dynamic panel.

The presence of a lagged dependent variable among the explanatory variables gives the model a "long memory," in the sense that the initial information is not lost, even if *t* becomes very large. The equation cannot, however, be estimated using a simple pooled regression, as the lagged dependent variable is correlated with the error term; a condition that, in the ordinary least squares (OLS) estimator, generates the loss of equality and consistency property. A similar problem is determined by the presence of endogenous explanatory variables. If the explanatory variables are generated within the same model generating the dependent variable, in fact, the explanatory variables are correlated by definition with the error term and OLS becomes unusable.

Since the unobserved individual effects are sometimes correlated with explanatory variables, macroeconomists often use fixed effects regression and the least-squares dummy variables estimator. In particular, fixed effects are suitable when panel data do not represent a sample randomly drawn from a large universe, but coincide exactly with the countries under consideration. However, the presence of the lagged dependent variable among the explanatory variables can lead to biased estimates of coefficients. These biases, as Nickell (1981) points out, tend to zero when the time dimension of the panel tends to infinity and endogenous explanatory variables are absent.

In order to overcome the problem of the biased estimates for datasets with many cross-sectional and few time series data, several estimators have been proposed. The contribution of Anderson and Hsiao (1981), for example, suggests the use of a double procedure. They advise first to transform the equation from levels to differences and then to use instrumental variables to "replace" the lagged dependent variable difference. In fact, the lagged dependent variable continues to be correlated, regardless of the transformation, with the difference of the error term. As instrumental variable to be used for the IV-2SLS estimator, Anderson and Hsiao suggest the difference of the two periods lagged dependent variable, which is correlated with the variable to be instrumented but not with the error term. However, Arellano (1989) notes that when the two periods lagged dependent variable is taken in levels, rather than in differences, it is a better solution. It is in fact correlated with the difference in the lagged dependent variable to be "instrumentalized" uncorrelated with the error term and it allows sparing an observation, thus gaining in degrees of freedom.

Although Anderson-Hsiao's estimator presents some valuable features, such as consistency and simplicity of use, it is not efficient as it does not use all possible orthogonality conditions and it does not take into account the structure of errors. One response to these limitations is provided by Arellano and Bond (1991), who use the generalized method of moments (GMM) estimator in first differences. The assumption underlying Arellano-Bond's proposal is the lack of serial correlation in error terms. On this basis, they note that it is possible to gain efficiency by exploiting all the moment restrictions, that is, by using as instruments all the values of the lagged dependent variable of two or more periods and all the values of the regressors when the latter are predetermined or strictly exogenous.

However, these gains in efficiency vanish if the autoregressive coefficients are close to unity or if the ratio between individual effect variance and idiosyncratic error variance is very high. When the autoregressive process is very persistent, in fact, there is a weak correlation between the first differences of the dependent variable and the lagged variables, and the orthogonality condition is fully satisfied. This is an issue that has been overcome in the contributions of Arellano and Bover (1995), and Blundell and Bond (1998). They suggest introducing additional conditions on the moments, considering the orthogonality between differences in dependent variables and disturbances in different equations of the observed cases. By so doing, they define a linear extended GMM estimator using lagged differences $\Delta a_{i,t-1}$, and lagged levels $a_{i,t-1}$ as instrumental variables in first difference equations. These solutions facilitate an increase in accuracy of the regression coefficients estimation, especially in cases where the extension of time is significantly lower than the extension of the sectional panel (Baltagi, 2005).

Since the techniques proposed by Arellano-Bover and Blundell-Bond portend significant gains in efficiency, especially according to our dataset structure, we use this estimator through a special application available in Stata 10.

5. RESULTS

Tables 1 and 2 show the results of the estimates and the implicit values of the model's coefficients, such as conditional convergence (λ), the physical capital elasticity of TFP when the quality of institutions is excluded (θ), the human capital elasticity of TFP when the quality of institutions is excluded (ω), "coefficient of institutional variation" on physical capital elasticity (φ_k) and "coefficients of institutional variation" on human capital elasticity (φ_h).

In particular, Table 1 shows estimates based on TFP calculated by setting the relative contribution of physical capital to production at 0.30. The table contains estimates related to all of the 121 observed countries and to a subset of countries with levels of institutional quality below to the world average (measured by the Knack-Keefer index). Moreover, the table includes estimates with time delays (of the explanatory variables with respect to the dependent variable) of 1, 3 and 5 years. The same structure is also used in Table 2, which shows the estimates based on the TFP calculated by setting the relative contribution of physical capital to production at 0.40.

Table 1: Estimation of the model's coefficients, setting α=0.3 in the TFP calculation

Coefficient	All the observed countries			Subset of countries with levels of institutional quality below to the average		
	t−1	*t*−3	*t*−5	*t*−1	*t*−3	*t*−5
ρ	0.9203	0.9655	0.9601	0.8982	0.9397	0.9449
	(77.37)	(80.16)	(82.56)	(56.70)	(55.50)	(60.36)
β_1	−0.0126	−0.0244	−0.0125	−0.0363	−0.0169	−0.0179
	(−1.78)	(−3.23)	(−1.69)	(−3.54)	(−1.49)	(−1.63)
β_2	0.2900	0.3187	0.1985	0.2569	0.2172	0.1409
	(5.75)	(5.90)	(3.97)	(3.16)	(2.62)	(1.89)
β_3	0.0003	0.0000	−0.0002	0.0003	0.0000	−0.0002
	(3.54)	(0.20)	(−2.00)	(2.73)	(−0.26)	(−2.03)
β_4	−0.0023	−0.0006	0.0016	−0.0021	0.0000	0.0027
	(−2.27)	(−0.58)	(1.74)	(−1.33)	(0.01)	(2.01)
Constant	0.0034	0.0031	0.0025	−0.0030	−0.0126	−0.0052
	(3.43)	(2.94)	(2.52)	(-0.38)	(−1.64)	(−0.79)
Implicit λ	**0.0361**	**0.0152**	**0.0177**	**0.0466**	**0.0270**	**0.0246**
Implicit θ	−0.1581	**−0.7072**	−0.3133	**−0.3566**	−0.2803	−0.3249
Implicit ω	**3.6386**	**9.2377**	**4.9749**	**2.5236**	**3.6020**	**2.5572**
Implicit φ_k	**−0.0238**	0.0000	**0.0160**	**−0.0083**	0.0000	**0.0112**
Implicit φ_h	**−0.0079**	−0.0019	**0.0081**	−0.0082	0.0000	**0.0192**
Instrumental variables	280	235	194	280	235	194
Wald χ^2	15467.75	13919.62	14640.82	6213.97	5891.41	7001.40
df	5	5	5	5	5	5
(P>Chi-square)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	2647	2407	2166	1393	1267	1141

Z-statistic is reported in brackets. TFP: Total factor productivity

Table 2: Estimation of the model's coefficients, setting α=0.4 in the TFP calculation

Coefficient	All the observed countries			Subset of countries with levels of institutional quality below to the average		
	t−1	*t*−3	*t*−5	*t*−1	*t*−3	*t*−5
ρ	0.9122	0.9632	0.9555	0.8920	0.9371	0.9375
	(78.68)	(81.29)	(84.30)	(57.09)	(55.54)	(60.78)
β_1	−0.0186	−0.0251	−0.0119	−0.0441	−0.0164	−0.0129
	(−2.77)	(−3.38)	(−1.63)	(−4.34)	(−1.40)	(−1.14)
β_2	0.3020	0.2870	0.1639	0.2817	0.1901	0.1231
	(5.86)	(5.27)	(3.26)	(3.48)	(2.29)	(1.65)
β_3	0.0004	0.0000	−0.0002	0.0004	0.0000	−0.0002
	(4.12)	(−0.06)	(−2.35)	(3.06)	(−0.34)	(−1.94)
β_4	−0.0030	−0.0004	0.0019	−0.0027	0.0002	0.0025
	(−2.90)	(−0.36)	(1.97)	(−1.69)	(0.11)	(1.81)
Constant	0.0034	0.0029	0.0023	−0.0027	−0.0102	−0.0031
Implicit λ	**0.0399**	**0.0163**	**0.0198**	**0.0496**	**0.0282**	**0.0280**
Implicit θ	**−0.2118**	**−0.6821**	−0.2674	**−0.4083**	−0.2607	−0.2064
Implicit ω	**3.4396**	**7.7989**	**3.6831**	**2.6083**	**3.0223**	**1.9696**
Implicit φ_k	**−0.0215**	0.0000	**0.0168**	**−0.0091**	0.0000	**0.0155**
Implicit φ_h	**−0.0099**	−0.0014	**0.0116**	**−0.0096**	0.0011	**0.0203**
Instrumental variables	280	235	194	280	235	194
Wald χ^2	13073.02	11801.11	11966.73	5641.80	5289.42	5956.86
df	5	5	5	5	5	5
(P>Chi-square)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Observations	2647	2407	2166	1393	1267	1141

Z-statistic is reported in brackets. TFP: Total factor productivity

In both tables we can see that the coefficient ρ is statistically significant, independently of the coefficient α used to calculate TFP, of the countries considered and of the time delay used. The variable ρ is implicitly tied to the value of λ, that is, the coefficient of conditional convergence in TFP. It shows high values in estimates related to the subset of countries with low levels of quality of institutions and, in general, in the estimates with one-period lags. These conditional convergence coefficients range between 4.96% (Table 2 - fifth column) and 1, 52% (Table 1 - third column). This confirms the hypothesis of TFP convergence advanced by Alexander Gerschenkron back in 1962 (later confirmed by many other authors) and is consistent with estimates reported in the contribution of Boulhol (2004). Based on Penn World Table and MINEFI database, Boulhol notes that technological convergence is influenced by the quality of institutions, and that the annual rate of this convergence ranges between 0% and 12.4%.

Unlike the conditional convergence coefficient, the estimates of parameter β_1 - implicitly linked to the role of physical capital in the TFP dynamics when the quality of institutions is excluded (θ) - are not always statistically significant. For example, θ is significant in countries with low quality of institutions when the explanatory variables lag is 1 year, while the significance disappears when the lags increase. However, the elasticity is negative and statistically significant in the estimates for the 121 countries, when the lags are 1 or 3 years; while it vanishes for a lag of 5 years. Although not as absolute, the negative relationship emerging between changes in TFP and the change in physical capital confirms the claims of Klenow and Rodriguez-Clare (1997), according to which the inverse relationship between accumulation of physical capital and TFP growth may indicate an overestimation of the physical capital contribution in GDP per worker. This condition suggests wide variations in efficiency between different types of investments (such as between public investment and private investment). The loss of statistical significance of the coefficient in the long run, then, could be connected to a higher social return of physical capital compared to private return, that, precisely in the long run, tends to underestimate the role of the accumulation factor being examined.

Coefficient β_2 proves statistically significant in all different estimates. As elaborated above, this coefficient is implicitly linked to the human capital elasticity of TFP when the quality of institutions is excluded, that is the value of ω. This value assumes a positive sign, emphasizing the direct influence of the process of human capital accumulation on TFP growth; an influence which significantly grows when time delays increase from 1 to 3 years, while it tends to decrease when the delay time increases further on. Juxtaposing the two tables, it is also possible to observe a lower ω in the countries with a lower quality of institutions. In these countries, this elasticity takes values between 3.60 and 1.96 (values equal to about half compared to the estimated for the whole set of 121 countries surveyed).

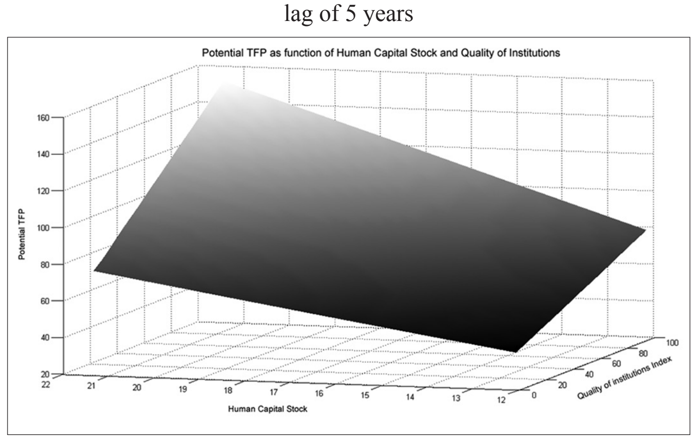
The role of "coefficients of institutional variation" on TFP growth is particularly interesting. To analyze this impact of institutions we must take into account time delays. In fact, the φ_k and φ_h coefficients (implicitly determined on the basis of the estimated parameters β_3 and β_4) have different signs and different significance according to the extent of time delays between dependent and explanatory variables. Both φ_k and φ_h assume negative signs when time delays are 1 year, lose their statistical significance for time delays of 3 years and become positive when the time delays are 5 years. In the short term, therefore, institutions seem to play a "mitigating" role in the effects produced by physical and human capital on TFP, while in the medium and long terms, institutions tend to "amplify" the functions of the accumulation process on TFP. This evidence points to the non-linearity in the time of the action exerted by the set of formal and informal rules characterizing economic and social relations. In the short term, in fact, an improvement of the institutional framework can constitute a rupture in the pre-existing competitive framework, with high costs for the overcoming of barriers to entry and innovation. Only in longer time periods, when the entrance of new companies and the introduction of new technologies have occurred, the role of the quality of institutions in favoring TFP can emerge in all its evidence.

Here, it is interesting to note the analogy with the response of water to thermal variations. As is well known, in fact, an increase in temperature between 0 and 4°C does not generate an expansion of the volume of water, but instead a contraction of its volume. Only for temperatures over 4°C does thermal dilation occur. This attitude is tied to the circumstance that the energy provided by external heat does not increase the energy of thermal agitation of molecules, but is used to break the rigid crystal structure of ice, with the breaking of the so-called "hydrogen bridges" and the transition to the liquid phase.

In economic systems a similar behaviour appears to be recorded: In these, the increase in quality of institutions may begin to unfold its effects on TFP only after the rupture of certain configurations. Thus, initially, any change in the institutional framework will not engender an increase in growth rates of TFP, but instead will serve to fuel changes in configuration that will render the economic system capable of growing in the long term.

To grasp the strength that variations of the institutional framework exercise on TFP in the long term, we present a three-dimensional graph (Figure 1), in which the potential level of TFP is a function of the stock of human capital (a statistically significant variable in all estimated configurations) and of the index of institutional quality. To construct this graph we used the estimates of parameters indicated in the fourth column of Table 2, that refer to all observed countries and to time lags of 5 years. The graph makes evident the capability of institutions to "amplify" the effects exercised by human capital on potential TFP. Observing the different slopes in correspondence to minimum and maximum values for the stock of human capital (left and right margin of the surface in the figures) it appears obvious that the quality of institutions has the effect of amplifying the impact of human capital on potential TFP, and that this effect is positively correlated to the intensity and actual diffusion of the stock of human capital. Variations in the institutional framework, thus, appear capable of penetrating more deeply into the heart of the market system when the basic

Figure 1: Esteem of the changes of the potential total factor productivity (log scale) as function of human capital (log scale) and quality of institution for the whole panel of countries using a temporal lag of 5 years



generative factors of TFP (that we have related to the stalks of capital) are present in a broader and more widespread way in the country.

6. CONCLUSIONS

Combining a focus on growth with the attempt to discuss accumulation and TFP has a long history in specialized economic literature. However, in this study we tried to overcome this approach, with the premise that the opposition between accumulation and TFP is an oversimplification of reality.

Rather than opposed to each other, the accumulation processes and TFP are in fact connected by complex non-linear relations, which are amplified or attenuated by the system of rules that governs countries' economic and social life.

The development of a specific model that tries to combine different theoretical approaches helped us shed light on some of the links involving the relationship between TFP and the accumulation processes both in relation to physical capital and to human capital. In order to have cognizance of the role played by time in this kind of problem, we also took into account some lags in the action exerted by the accumulation processes on TFP.

The results show the existence of statistically significant links in the different cases observed. For example, in the short term, the process of physical capital accumulation has an inverse relationship with TFP. This relationship is mitigated, however, if we take into account the effect of institutions. A high level of quality of institutions tends to contain the substitution effect that the accumulation process has on TFP, although this substitution effect naturally tends to disappear in the long term. Conversely, the process of human capital accumulation registers a positive relationship with TFP itself. This positive relationship affects all the observed periods, although its intensity has an inverted U-shaped pattern. Even in the process of human capital accumulation, the effect exerted by institutions is significant both in the short and in long term. However, while in the short-term institutional action tends to mitigate the effect of the accumulation process on TFP, in the long run this effect is reversed, becoming an amplifier of the action exerted by human capital on TFP. This effect is due to the very nature of institutions. Every institutional change, in fact, firstly generates a rupture of the pre-existing competitive framework and successively leads to a variation in the capacity of TFP to respond to variations of its generative factors.

The results obtained allow us to describe, albeit in a preliminary and not exhaustive way, a framework for the analysis of relationships between accumulation processes and TFP. While accumulation and TFP have direct and independent effects on growth, they also produce cross external effects (through the interactions network described), which indirectly act on growth itself. These effects are not uniform in time. But they are significantly affected by the institutional dimension, that produces effects similar to those that temperature exercises in the thermal dilatation of bodies, in other words expanding or mitigating the effects of the process of accumulation on TFP.

The analogies that we have underlined with principles of thermal expansion allow us both to better understand the behaviour of institutional variations, and raise new questions.

In fact, the law of linear thermal expansion is only an approximation and it can be used until the effect of pressure is negligible. If the proposed model produces a good description of the economic evolution of some countries, an interesting question would be: Is there an equivalent of pressure in the economic context? Furthermore, as it is well known, in nature there is not a single coefficient of thermal dilation, but this varies in relation to the specific chemical-physical structure of bodies. On the basis of this, it appears spontaneous to ask if this analogy may also be extended to economic phenomena. In other words, can we identify countries that have an increased response to institutions with respect to others? Also, in the case of time lags necessary to break the old configurations and to create new ones, it may be interesting to ask whether these lags depend on processes of accumulation, or if they are tied to the level of concentration and spatial distribution of human and physical capital in the economy. These are, of course, open questions that leave space to future research and reflection.

Looking towards the future, increased efforts must be made to overcome the assumption of exogeneity of institutional change and of the technological frontier that we made us in this contribution.

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Annex Table 1: The observed countries

Albania
Algeria
Argentina
Armenia
Australia
Austria
Bahrain
Bangladesh
Belgium
Bolivia
Botswana
Brazil
Brunei
Bulgaria
Cameroon
Canada
Chile
China Version 2
Colombia
Democratic Republic of the Congo
Republic of Congo
Costa Rica
Cote d`Ivoire
Croatia
Cyprus
Czech Republic
Denmark
Dominican Republic
Ecuador
Egypt
El Salvador
Estonia
Finland
France
Gabon
The Gambia
Germany
Ghana
Greece
Guatemala
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Republic of Korea
Kuwait
Latvia
Lebanon
Liberia
Libya
Lithuania
Luxembourg
Malawi
Malaysia

Annex Table 1: (Continued)

Mali
Malta
Mexico
Mongolia
Morocco
Mozambique
Namibia
Netherlands
New Zealand
Nicaragua
Niger
Norway
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Romania
Russia
Saudi Arabia
Senegal
Serbia e Montenegro
Sierra Leone
Singapore
Slovak Republic
Slovenia
South Africa
Spain
Sri Lanka
Sudan
Sweden
Switzerland
Syria
Taiwan
Thailand
Togo
Trinidad and Tobago
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Venezuela
Vietnam
Yemen
Zambia
Zimbabwe