Dipartimento di Scienze Economiche
Università degli Studi di Firenze

Working Paper Series

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Working Paper N. 09/2012
April 2012

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www.dse.unifi.it

Stampato in proprio in Firenze dal Dipartimento Scienze Economiche
(Via delle Pandette 9, 50127 Firenze) nel mese di Aprile 2012,
Esemplare Fuori Commercio Per il Deposito Legale
agli effetti della Legge 15 Aprile 2004, N.106

The conditional convergence in TFP levels

On the relationship between TFP, processes of accumulation and institutions

by

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March 11, 2012

Abstract

In this paper, we discuss the relationship between productivity, accumulation and institutions. We start from the idea that accumulation and productivity are connected by complex non-linear relations, which are amplified or attenuated by the system of rules that affects trade, decisions and preferences of economic actors.

In order to show these connections, we have built a specific model that helps us shed some light on the ties involving this multi-dimensional relationship, which goes from institutions to the stock of physical and human capital and from this latter to productivity. On these ground, we propose a circular relationship between the existing literature on "barriers" and on "appropriability".

JEL Classification: O43, O47, E02

Keywords: Growth, Total Factor Productivity, Accumulation Processes, Institutions

Acknowledgements

The authors would like to thank Pier Francesco Asso, Naor Ben-Yehoyada, Sebastiano Nerozzi, Giorgio Ricchiuti and Filiana Scaduto for their contributions to the preparation of this paper.

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Introduction

Whether economic growth is determined by the processes of accumulation or total factor productivity (TFP) is still a debated issue. The prevailing view favors the TFP (Klenow and Rodriguez-Clare, 1997, Easterly and Levine, 2001). It should be noted, however, that the prevailing approaches of analysis neglect the possibility of external cross-effects between factors accumulation and productivity. For example, if social return of capital is higher than the private one, the growth accounting tends to give more weight to the role of productivity, although ultimately the changes in wealth are due to the accumulation factor.

The idea that motivates this work is that the contrast between accumulation and productivity is actually an oversimplification of reality. In fact, the process of economic growth is the result of a complex combination of factors that interact in different ways. In this dimension, it is no longer sufficient to determine whether or not productivity is the main driver of growth. Rather, we should go back to the system of relations that binds together the factors of production. In fact, the economic literature already offers insights regarding the links between individual factors of accumulation and productivity, but a systemic view of these connections is still poorly analyzed.

Edward Wolff (1991), for example, stressed that the 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, writes Wolff, the association between technology and capital is reduced significantly 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 productivity was already present in the work of Moses Abramovitz (1986), who emphasizes the existence of a strong relationship between productivity and "social capacity" to absorb new technologies. Here, "capacity" is linked both to quality of institutions and the populations' education level. Also in Robert Hall and Charles Jones (1999), capital accumulation and technology are related to the "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 firms accumulate capital. More recently, Chris Papageorgiou and Viera Chmelarova (2005) record evidence for a relationship of complementarity between physical capital and human capital, which nevertheless has the characteristics of non-linearity. If 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 the factors of accumulation and productivity, taking into account the role played by institutions. In fact, institutions can deeply affect both the direction and the intensity of such relationships, because of 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 1) during the period 1985-2009.

The paper is organized as follows. After a reminder of the economic literature on the TFP, we present a model of conditional convergence in TFP. In subsequent chapters, we discuss the econometric technique we use to estimate the parameters of the model and we describe the data used in the analysis. Finally, we present and discuss the results obtained in order to identify the existence of a relationships network.

The total factor productivity in the economic literature

An analysis of recent economic literature, clarifies how the levels and growth rates of TFP vary significantly across countries. So much so, that several authors, like Elhanan Helpman (2004), have inquired into the root causes of these differences, observing also a strong correlation between changes in TFP and changes in national wealth.

It is interesting to note that this idea was still under-discussed as late as the early 90s. In the contribution of Gregory Mankiw, David Romer, and David Weil (1992), for example, the growth rate of TFP is assumed to be common to all countries, while the initial level of TFP is considered on the basis of some random variables unrelated to the factors of production. These assumptions help the authors to support the idea that all international variations of economic growth rates can be brought back into neoclassical hypothesis regarding the distance from the steady state and the presence of diminishing returns. In particular, the authors claim that 78% of international variations may be simply accounted for by the process of accumulation of physical capital and human capital. This conclusion is not accepted by Gene Grossman and Elhanan Helpman (1994), who argue that the estimates of Mankiw, Romer and Weil are incorrect because of very restrictive assumptions on TFP growth rates. In fact, Grossman and Helpman record the existence of a positive correlation between the TFP growth rates and the ratio of investment to GDP. On the basis of this correlation, they articulate their criticism of the contribution of Mankiw, Romer and Weil. In particular, the two economists write, "*if investment rates are high where productivity grows fast, the coefficient on the investment variable will pick up not only the variation in per capita income due to differences in countries' tastes for savings, but also part of the variation due to their different experiences with* *technological progress*". In the presence of a positive correlation between TFP and investment, therefore, the role of investment in economic growth is overestimated. A similar conclusion comes from Nazrul Islam (1995), whereby the differences in international growth rates are more adequately explained by TFP levels than by changes in investment rates. Islam's argument is based on the idea that the assumption used by Mankiw, Romer and Weil about the TFP level is not acceptable. In his view, in fact, the condition of perfect independence of the explanatory variable levels used in the TFP convergence equation (condition underlying assumption of random variability) appears excessive. To correct this, Islam proposes a fixed effects panel model, which shows a high and persistent volatility of national TFP levels . This volatility allows him to account for international differences in economic growth rates. In their critique of the assumption of random TFP variability, Francesco Caselli, Gerardo Esquivel and Fernando Lefort (1996) point out that this assumption is necessarily violated by the dynamic nature of growth patterns. Consequently, in order to estimate the national levels of TFP, the three authors suggest the use of the generalized method of moments, which can provide accurate estimates even in the presence of endogenous explanatory variables. The results obtained from the estimates of Caselli, Esquivel and Lefort confirm the wide variability in levels of TFP, which is considered a pervasive and important variable in the determination of the stationary states of single countries.

To account for this variability, by the early 90s, some economists have underlined the role of research and development (R&D) as the first cause of technological progress and, in this way, of productivity. Paul Romer (1990), for example, suggests that companies invest resources in research to develop new products, which are protected by patents. Through research, innovative companies get monopoly power in the goods market with subsequent extra profits, which in turn generate incentives for further investments in R&D. The investment in R&D, however, generates knowledge that is not fully harnessed in the legal system of patent protection and helps increase the stock of free knowledge. Since this stock has a positive effect on productivity of employed resources in R&D, the cost of investment in R&D tends to decrease over time, offsetting the reduction in extra profits associated with rise in the number of available products on the market. Consequently, the flow of resources employed in R&D remains constant, thus ensuring a constant growth rate of technological progress, which will be endogenously determined. In other words, such a technological progress depends on the size of the markets, the share of human capital employed in R&D and the annual rate of savings. An alternative approach to Romer is developed by Philippe Aghion and Peter Howitt (1992), who base their argument on the assumption that technological progress is the result of a process of "creative destruction", whereby it implements a progressive improvement in the quality of products. Each innovation incorporated in the production of highest quality goods captures a monopoly revenue but, at the same time, it destroys the revenue of the replaced lower quality goods. The introduction of an innovation, however, leaves no memory - it does not change the system's ability to produce more innovations. In fact, these are the random result of current R&D, which depends on the number of workers trained in its use. This quantity can be fixed on the basis of the expected amount of future R&D (on which the present monopoly revenue depends) and the intrinsic characteristics of the economic system (as, for example, the growth rate of educated population or the breadth markets). As may be noted, the findings of Aghion and Howitt are not particularly different from those of Romer, exposing themselves to criticism from those who see in these models the presence of unrealistic effects of scale (Charles Jones, 1995). In response, new interpretive schemes have been developed in relation to the idea that there is a positive relationship between productivity and "research intensity" rather than between productivity and investment in R&D. Alwyn Young (1998) suggests that productivity growth depends on improving the quality of products but, unlike Aghion and Howitt, he believes that increased size of the economy also causes an increase in the variety of available products. Therefore, efforts in R&D towards improving quality are spread across a growing number of products. As a result, the additional resources obtained from scale effects and directed toward R&D are just enough to compensate for a greater variety of products, without producing any change on productivity. An alternative approach is offered by Peter Howitt (2000). He moves from the idea that quality improvements associated with innovations become increasingly complex over time because of advances in technological frontier. This is seen as the result of innovative actions carried out globally but, at the same time, as the body of knowledge that is freely available. In this context, Howitt notes that a country could register a constant growth of productivity if, and only if, its annual expenditure on R & D grows as fast as the technology frontier; a condition that involves some structural elements of the economy, such as savings and investment, effectiveness of research and incentive system.

As emphasized by Verspargen Bart (1996), Jonathan Eaton and Samuel Kortum (1997) and Charles Jones (2002), investments in R&D provide an interesting interpreting tool for productivity. However, their use is limited to more developed economies, due to the high degree of concentration at which such investments occur in these countries. In fact, UNESCO data indicates that over 80% of total global investment in R&D are concentrated in 5 countries (USA, Japan, Germany, France and Great Britain) and 90% of them are concentrated in 12 countries. To analyze productivity in the low and middle income economies (that is, productivity in most countries of the world), we must therefore refer to different interpretive schemes. Accordingly, researchers' attention is focused on "capacity" of each country "to absorb" technologies, independent of the places where they are produced. Such a capacity is already emphasized by Simon Kuznets (1966), who writes: "no matter where these technological and social innovations emerge – and they are largely the product of the developed countries – the economic growth of any given nation depends upon their adoption".

Within this literature, the contribution of Stephen Parente and Edward Prescott (1994) focuses on the barriers to the introduction of new technologies. Barriers that take different forms (such as regulatory and legal constraints, bribes to be paid, violence or strikes), but which always produce the same effect: an increase in the cost of introducing new technologies. If access to knowledge is free, the existence of barriers to innovation is the main constraint to productivity growth and, consequently, to economic growth. Following Parente and Prescott, we can see how each country experienced several barriers related to institutional environment and, consequently, has different levels of efficiency in resource use. According to this concept, already noted by the economic historian Joel Makyr (1990), each society has some stabilizing forces that tend to protect the status quo and discourage innovations that could change the society's vested interests. If these forces dominate the need for technological creativity, they block economic growth. In order to provide an answer to the question why poor countries do not use the best technology available, in a subsequent article, Stephen Parente and Edward Prescott (1999) condemn the role of monopoly rights. According to the authors, the mechanism by which monopoly rights impede technological progress is a strategic mechanism. It is as if, in each economic sector, a game develops between those who offer production services protected by monopoly and their potential competitors. The first impose rules, work practices, and costs for the use of current technologies. The latter can offer superior technology, but only after overcoming the resistance of the monopolists, whose strength depends on the protection system and the number of people who already benefit from protection. Since the resistance of the monopolists is the condition that they receive an income, these will increase lobbying activities. Consequently, the economy registers a failure in the adoption of new technologies and inefficient use of current resources. According to Parente and Prescott, it is not therefore the absence of a monopolistic system of protection (a la Schumpeter) to hinder technological progress in developing countries, but rather the very presence of such monopoly rights. The developing countries can, in fact, adopt new technologies, drawing from previous experience abroad. The adoption of such a superior technology does not require, however, large investments, but rather a generic investment company for which, to be stimulated, does not need monopoly protection. In conclusion, the two economists believe that the condition ensures that the largest productivity growth lies in the free market access and the elimination of any monopoly protection.

In fact, attention to the "capacity to absorb" new technology has not developed solely on the front of the impediments to the transfer of specific technologies but is also directed towards "appropriability". In the contribution of Susanto Basu and David Weil (1998), for example, technology is assumed to be freely transferable and immediately available, but even a country cannot use new technology until it reaches a level of development in which this technology is appropriate for its needs. The authors assume, in fact, that there is a close relationship between technology and capital intensity (physical and human), since technology helps tie every single one and only one level of capital per worker. In this view, every technological advance is intended as an expansion of production possibilities for a given level of capital. Since developing countries can use technologies developed in advanced countries only if they have reached a sufficient level of development, the relationship between growth and capital accumulation process is highly nonlinear. The paradigm of "appropriate technology" is taken up by Daron Acemoglu and Fabrizio Zilibotti (2001), who stress the existence of differences in the productivity of countries, even in the absence of barriers to technology transfer. They observe that most of the technologies used in developing countries come from developed countries. These technologies are, therefore, the result of investments made to meet the specific needs of developed countries, thus the optimizing use of resources available in them. Since one of the most valuable assets in developed countries is the high educational level of workers, new technologies tend to be complementary to higher skills. Consequently, although there may not be present institutional obstacles to the introduction of new technologies, developing countries find themselves working with technologies totally inadequate for employees' training level. The mismatch of skills between developed countries and developing countries thus contributes to the creation of differences in productivity levels and to a widening of the gap in income per capita (between developing and developed countries). The low productivity obtained from the technologies imported from developed countries, however, should not be solely attributed to the differences in training (although these appear to be the most important) but also to institutional and cultural diversity, which, according to Acemoglu and Zilibotti, require specific investigation.

In this paper, the hypothesis that the "capacity to absorb" technologies can be a practical tool for interpreting the TFP is accepted. It appears natural to assume that some technologies may be more or less productive than others, in relation to the different mix of factors available in each and every country. In fact, while the "capacity to absorb" technologies can be placed in relation to the stock of physical and human capital on the one hand, this relation cannot, on the other hand, disregard the system of rules that affect trade, the choices and preferences economic actors. If the availability of resources affects the absorption of technology, institutions affect the degree of effectiveness with which the resources themselves affect the absorption process. Just on the basis of this multi-dimensional relationship, which proceeds from institutions to resources and from the latter to absorptive capacity, we propose a circular relationship between the literatures on "barriers" and on the "appropriability".

The model

The working hypothesis in this article 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:

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

where $\boldsymbol{A(t)}$ is the TFP of a specific country, at a given period; $\boldsymbol{A^*(t)}$ is the "potential" TFP for this country at the same period, and $\boldsymbol{\lambda}$ is related to the conditional convergence coefficient. In particular, the "potential" TFP is assumed as a function of the stock of physical capital and human capital, where both are weighted using the quality of the country's institutions.

The effect of the quality of institutions is to moderate or amplify the impact of the physical and human capitals on the potential TFP. To model this effect, the "neutral" elasticities of the potential TFP with respect to physical and human capitals have been modified, assuming a specific relation between elasticity and quality of institutions. In the following, the variable $\boldsymbol{k}$ and $\boldsymbol{h}$ are the physical capital and human capital respectively, per worker, and $\boldsymbol{I}$ is a synthetic index representing the quality of the country's institutions. A variation in the quality of institutions in a single country, $\Delta\boldsymbol{I}$, might modify the elasticity of the potential TFP with respect to, for example, physical capital, $\Delta\boldsymbol{\theta} = \boldsymbol{\theta_f} - \boldsymbol{\theta_i}$. We pose the force and direction of this variation depends linearly on the initial value of elasticity $\boldsymbol{\theta_i}$ and on $\Delta\boldsymbol{I}$, with $\boldsymbol{\varphi_k}$ as coefficient. So, we have:

$$\Delta\theta = \varphi_k \theta_i \Delta I$$

Therefore, the coefficient $\boldsymbol{\varphi_k}$ represents the variation of the unitary elasticity ($\boldsymbol{\theta_i} = \boldsymbol{1}$), when the index of the quality of institution varies of one unity ($\Delta\boldsymbol{I} = \boldsymbol{1}$).

Moreover, with a simple manipulation, one obtains:

$$\theta_f = \theta_i\left(1 + \varphi_k \Delta I\right)$$

and, if we indicate with $\boldsymbol{\theta}$ the "neutral" elasticity, when $\boldsymbol{I} = \boldsymbol{0}$, we can write, for the "total" elasticity, $\boldsymbol{\bar{\theta}}$, of the potential TFP with respect to the physical capital:

$$\bar{\theta} = \theta(1+\varphi_k I)$$

Similarly, for the elasticity with respect the human capital, one obtains:

$$\bar{\omega} = \omega(1+\varphi_h I)$$

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

Formally:

$$A^*(t) = k^{\theta(1+\varphi_k I)} h^{\omega(1+\varphi_h I)} T(t) \tag{2}$$

where $\boldsymbol{k}$ represents the physical capital per worker, $\boldsymbol{\theta}$ represents the "neutral" physical capital elasticity of TFP, $\boldsymbol{h}$ represents human capital per worker, $\boldsymbol{\omega}$ represents the "neutral" human capital elasticity of TFP, $\boldsymbol{I}$ represents the synthetic index of the quality of national institutions, φ_k represents the "coefficient of institutional variation" on physical capital elasticity, φ_h the "coefficient of institutional variation" on human capital elasticity, and ***T(t)*** represents the exogenous index of growth of the technological frontier.

As can be observed, when the quality of institutions is excluded from the calculation, the equation (2) returns a classic Cobb-Douglas. When that quality enters into the calculation, it can generate two different effects: an amplification or mitigation of elasticity of TFP with regard to the considered variables. The functional form was particularly chosen to discern between the direct effect of the considered variables on potential TFP and the effect of the institutions on the whole of these same variables.

The idea that human capital affects productivity belongs to a long standing scholarly tradition that dates back to the contribution of Richard Nelson and Edmund Phelps (1966). Empirical evidence of the comparative advantage of higher education levels among workers on innovation was obtained by Gregory Wozniak (1984), Ann Bartel and Frank Lichtenberg (1987), Andrew Foster and Mark Rosenzweig (1995). Other interesting contributions were by Jess Benhabib and Mark Speigel (1994), Mark Bils and Peter 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 productivity, rather than through its direct effects (as productive factor) on the production function. The idea that physical capital may affect the rate of productivity growth is related, on the other hand, to the contributions of Moses Abramovitz (1979), Edward Wolff (1991), Peter Klenow and Andres Rodriguez-Clare (1997), Susanto Basu and David Weil (1998). While they accept the existence of a functional link between physical capital and productivity, they do not agree about 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 productivity. They explain it as a consequence of the inefficient accumulation of physical capital in the public sector. On the other hand, the idea that institutions may affect productivity is quite recent in the vast literature on institutions (North and Thomas, 1973; North, 1981 and 1990, Grief, 1993, Engerman and Sokoloff, 1997; The Gate , Lopez-de-Silanes, Shleifer and Vishny, 1998, Hall and Jones, 1999; Acemoglu, Johnson and Robinson, 2001 and 2005, Djankov, La Porta, Lopez-de-Silanes, and Shleifer, 2002, Glaeser and Shleifer, 2002; Gradstein, 2002 and 2004). As pointed out by Xavier 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 Elhanan Helpman (2004), who attempts to identify some original elements emerging in the recent literature. The observed differences in the paths of economic growth could be explained the Helpman's opinion, through the differences in the institutional structures. These differences affect the incentives to innovate, develop of new technologies, reorganize production, and accumulate physical and human capital. The particular relationship between institutions and incentives to innovate was recently developed by Edinaldo Tebaldi and Elmslie Bruce (2008). According to them, the 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.

As may be evident, therefore, 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 on the "capacity to absorb" technologies.

Returning to the model, after taking the logarithm of $A^*(t)$, one can rewrite the equation (1) in the following form:

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

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

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

Integrating on the temporal interval $[t_1, t_2]$, one obtains:

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

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

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

The assumptions used in integration is quite common in the panel estimates on growth. For example, Nazrul Islam (1995) and Francesco Caselli, Gerardo Esquivel and Fernando Lefort (1996) assume that the independent variables in their models (*i.e.*, the savings rate, the rate of population growth, and the stock of human capital) are constant over five years.

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

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

where $\boldsymbol{\tau}$ is equal to ($\boldsymbol{t_2}$ - $\boldsymbol{t_1}$).

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

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

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

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

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

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

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

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

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

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

$$\beta_3 = \varphi_k \beta_1,$$

$$\beta_4 = \varphi_h \beta_2,$$

Moreover, adding the error term, one can write:

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

As is evident, the equation (4) represents a dynamic panel model. In order to estimate it, a transformation has to be implemented. In fact, it is necessary to eliminate the *time varying* component and to measure all the variables as deviations from the means. In other words, new variables are defined:

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

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

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

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

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

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

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

And consequently the equation, using these variables, is:

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

This is the equation that we will use. On its basis we can calculate the "neutral" physical capital elasticity of TFP, the "neutral" human capital elasticity of TFP, the "coefficients of institutional variation" and the coefficient of conditional convergence. In particular, we obtain these values as follow:

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

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

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

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

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

The 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, the perpetual inventory method was used. This method assumes that the stock of physical capital (***K***) in a given year is equal to 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, the approach suggested by Arnold Harbenger (1978) was applied. The depreciation rate was set at 0.05, while the investment data were taken from the National Accounts Main Aggregates Database of the United Nations (in U.S. dollars and constant prices 2005).

In order to calculate the human capital, we followed the suggestion of Robert Hall and Charles Jones (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 like as percentage differences of wages for different education levels. In order to implement this approach, we used the average years of schooling data published by Robert Barro and Jong-Wha Lee (2000) and the average rate of schooling return by George Psacharopulos (1994) equals to

0.134, for first four years of schooling; 0.101, for the second four years of schooling; and 0.068, for more than eight years of schooling.

The time series of workers for the 121 observed countries, have been 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 $\boldsymbol{A}$ is TFP, $\boldsymbol{y}$ is the GDP per worker, $\boldsymbol{\alpha}$ is the relative contribution of physical capital to production, $\boldsymbol{k}$ is the stock of physical capital per worker, and $\boldsymbol{h}$ 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 values normally used on growth accounting studies.

Among the different datasets on the quality of institutions, we used data from the International Country Risk Guide (ICRG), published yearly by the Political Risk Services Group. ICRG data include 22 variables, summarized in three sub-categories of risk: political risk, financial risk and economic risk. These three sub-categories combine to determine the Composite Risk Index.

In the following estimates, we used a particular indicator of the institutions' quality, which we called "Knack-Keefer index". This is, in the “strict sense", the quality indicator. Following the contribution of Stephen Knack and Philip Keefer (1995), the “index” is calculated averaging four specific variables, contained in the ICRG dataset representing the legal system, the corruption in government, the quality of the bureaucracy, and the risk of expropriation of private investment. The Knack-Keefer approach has been particularly used in some specific economic literature, as in the contributions of Robert Barro (1996), Jeffrey Sachs and Andrew Warner (1997), Robert Hall and Charles Jones (1999). Moreover, the Knack-Keefer index coincides with Xavier Sala-i-Martin's pragmatic conceptualization of institutions (2002), who suggests to look at institutions as a set of elements linked to the way in which society and economy operate in a modern capitalist system. In this sense, Sala-i-Martin focuses his attention on the opportunities of society and economy to enforce contracts, protect property rights, control corruption, as well as provide a transparent government and a legal system efficient.

The 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 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 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, because the lagged dependent variable is correlated with the error term; a condition that, in the OLS estimator, generates the loss of the fairness 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 that generates the dependent variable, in fact, the explanatory variables are correlated by definition with the error term and OLS becomes unusable.

Because the unobserved individual effects are sometimes correlated with the explanatory variables, macroeconomists often use fixed effects regression and the LSDV estimator. In particular, the fixed effects are suitable when the panel data do not represent a sample randomly drawn from a large universe but coincide precisely with the countries to be studied. However, the presence of the lagged dependent variable among the explanatory can lead to biased estimates of coefficients. These biases, as Stephen 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 propose, first, to transform the equation from levels to differences and, subsequently, 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 dependent variable lagged two periods, which is correlated with the variable to be instrumented but not with the error term. However, Manuel Arellano (1989) notes that when the two periods lagged dependent variable is taken in levels, rather than in differences, it is a better solution. Indeed, it is correlated with the difference in the lagged dependent variable to be "instrumentalized," uncorrelated with the error term and saves an observation, thus gaining in degrees of freedom.

Even if the Anderson-Hsiao estimator presents some valuable features, such as consistency and simplicity of use, it is not efficient because it does not use all possible orthogonality conditions and it does not take into account the structure of the errors. One response to these limitations is provided by Manuel Arellano and Stephen Bond (1991), who use the GMM estimator (generalized method of moments) in first differences. The assumption underlying the proposal Arellano-Bond is the absence 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 the individual effect variance and the idiosyncratic error variance is very high. When the autoregressive process is very persistent, in fact, there exists 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 Manuel Arellano and Olympia Bover (1995), and Richard Blundell and Stephen Bond (1998). They suggest to introduce additional conditions on the moments, considering the orthogonality between the differences in the dependent variables and the disturbances in different equations of the observed cases. In this way, they define a linear extended GMM estimator using lagged differences $\Delta \boldsymbol{a}_{i,t-1}$, and lagged levels $\boldsymbol{a}_{i,t-1}$ 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 (Baltag, 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. In addition, to verify the existence of an over-identification of restrictions on the moments, we use the Sargan test.

The results

Tables 1 and 2 show the results of the estimates and the implicit values of the model's coefficients, such as the conditional convergence ($\boldsymbol{\lambda}$), the "neutral" physical capital elasticity of TFP ($\boldsymbol{\theta}$), the "neutral" human capital elasticity of TFP ($\boldsymbol{\omega}$), the "coefficient of institutional variation" on physical capital elasticity ($\boldsymbol{\varphi_k}$) and the "coefficients of institutional variation" on human capital elasticity ($\boldsymbol{\varphi_h}$).

In particular, Table 1 shows the estimates based on the TFP calculated by setting to 0.30 the relative contribution of physical capital to production. The table contains estimates related to all 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, in the table are reported 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 to 0.40 the relative contribution of physical capital to production. Both tables also report the results of the Sargan test to verify the validity of over-identifying restrictions.

In both tables we can see that the coefficient $\boldsymbol{\rho}$ is statistically significant, independently of the coefficient $\boldsymbol{\alpha}$ used to calculate TFP, of the countries considered and of the time delay used. The variable $\boldsymbol{\rho}$ is implicitly tied to the value of $\boldsymbol{\lambda}$, 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 productivity 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 Hervé (2004). Based on the Penn World Table and MINEFI database, Boulhol notes that technological convergence is conditioned 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 $\boldsymbol{\beta_1}$, which is implicitly linked to the role of physical capital in the TFP dynamics ($\boldsymbol{\theta}$), are not always statistically significant. For example, the "neutral" physical capital elasticity of TFP is significant in countries with low quality of institutions when the explanatory variables lag is one 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 one or three years; while it vanishes for a lag of five years. Although not so absolute, the negative relationship that emerges between changes in TFP and the change in physical capital confirms the claims of Peter Klenow and Andres Rodriguez-Clare (1997), according to which the inverse relationship between accumulation of physical capital and TFP growth may indicate an overestimation of the contribution of physical capital in GDP per worker. This condition suggests wide variations in efficiency between the different types of investments (such as between public investment and private investment).

Statistically significant in all the different estimates is the coefficient $\boldsymbol{\beta_2}$. As elaborated above, this coefficient is implicitly linked to the "neutral" human capital elasticity of TFP, that is, the value of

ω. This value assumes a positive sign, emphasizing the direct influence of the process of human capital accumulation on productivity growth; an influence that grows significantly when time delays increase from one year to three years, while it tends to decrease when the delay time increases further. Looking at the two tables together, it is also possible to see a lower “neutral” human capital elasticity of TFP 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 entire set of 121 countries surveyed).

The impact of institutions in influencing the effect of the physical and human capital on the growth of TFP is significant as well. 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 magnitude of time delays between the dependent variable and the explanatory variables. Both φ_k and φ_h assume the negative signs when time delays are one year, lose their statistical significance for time delays of three years and they become positive when the time delays are five years. In the short term, therefore, the institutions seem to play a "mitigating" role in the effects produced by the physical and human capital on the 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 that characterize the economic and social relations.

If we pay attention to Tables 1 and 2, we notice some significant differences in the “coefficient of institutional variation” related to physical capital and human capital. In the case of physical capital, the "amplifying" effect produced by the institutions is greatest when one analyzes all the 121 countries. In the case of human capital, however, the "amplifying" role played by institutions seems to have a stronger effect on the subset of countries with an index of Knack-Keefer below average. These results lead us to hypothesize that the actions of institutions produce non-linear effects not only from the temporal point of view but also from the typological point of view. In other words, institutions’ effects change in relation to the accumulation process and to the quality of the institutional contexts.

Some conclusions

The combination of a focus on growth and an attempt to discuss accumulation and productivity has a long history in the specialized economic literature. This is, however, an approach that we try to overcome in this work, moving from the idea that the opposition between accumulation and productivity is an oversimplification of reality.

Rather than opposed to each other, the processes of accumulation and productivity 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 seeks to link together different theoretical approaches—such as the barriers to innovation or the abilities to absorb technology—helped us shed light on some of the ties involving the relationship between productivity and accumulation. To measure productivity, we have used to the concept of TFP and have observed 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 problems, we have considered also some lags in the action exerted by the processes of accumulation on productivity.

The results show the existence of statistically significant links in the several cases observed. For example, in the short term, the process of physical capital accumulation has an inverse relationship with productivity. This relationship is mitigated, however, if we take into account the effect of institutions. A high level of quality of the institutions tends to contain the substitution effect that the process of accumulation has on productivity, although this substitution effect tends naturally to disappear in the long term. Conversely, the process of human capital accumulation registers a positive relationship with productivity 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 the institution is significant both in the short and long term. However, while in the short-term institutional action tends to mitigate the effect of the process of accumulation on productivity, in the long run this effect is reversed, becoming an amplifier of the action exerted by the human capital on productivity. This could be related to the presence of barriers to innovation, which could contain the innovative thrusts until the accumulation of human capital becomes so important to produce substantial positive externalities.

The results obtained allow us to describe, albeit in a preliminary and not exhaustive, a framework for the analysis of the relationships between the processes of accumulation and productivity. While accumulation and productivity have direct and independent effects on growth, they also produce cross external effects (through the network of interactions that we have described), which act indirectly on growth itself. These effects are not uniform in time. But they are significantly affected by institutional dimension.

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

	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)*
costant	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**
Instr. variables	280	235	194	280	235	194
Sargan Test						
chi2	1223.962	917.1102	932.7946	696.882	540.9462	553.9763
df	274	229	188	274	229	188
(Prob > chi2)	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*
Observations	2647	2407	2166	1393	1267	1141

Note: z statistic is reported in brackets

Tab. 2. Estimation of the model's coefficients, setting $\alpha = 0.4$ in the TFP calculation

	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)*
costant	0.0034	0.0029	0.0023	-0.0027	-0.0102	-0.0031
	(3.49)	*(2.78)*	*(2.36)*	*(-0.34)*	*(-1.32)*	*(-0.47)*
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**
Instr. variables	280	235	194	280	235	194
Sargan Test						
chi2	1225.542	919.6288	923.4849	699.7783	556.5784	564.335
df	274	229	188	274	229	188
(Prob > chi2)	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*	*(0.0000)*
Observations	2647	2407	2166	1393	1267	1141

Note: z statistic is reported in brackets

Annex 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
Congo, Dem. Rep.
Congo, Republic of
Costa Rica
Cote d`Ivoire
Croatia
Cyprus
Czech Republic
Denmark
Dominican Republic
Ecuador
Egypt
El Salvador
Estonia
Finland
France
Gabon
Gambia, The
Germany
Ghana
Greece
Guatemala
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Ireland
Israel
Italy
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Korea, Republic of
Kuwait
Latvia
Lebanon
Liberia
Libya
Lithuania
Luxembourg
Malawi
Malaysia
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 &Tobago
Tunisia
Turkey
Uganda
Ukraine
United Arab Emirates
United Kingdom
United States
Uruguay
Venezuela
Vietnam
Yemen
Zambia

Zimbabwe